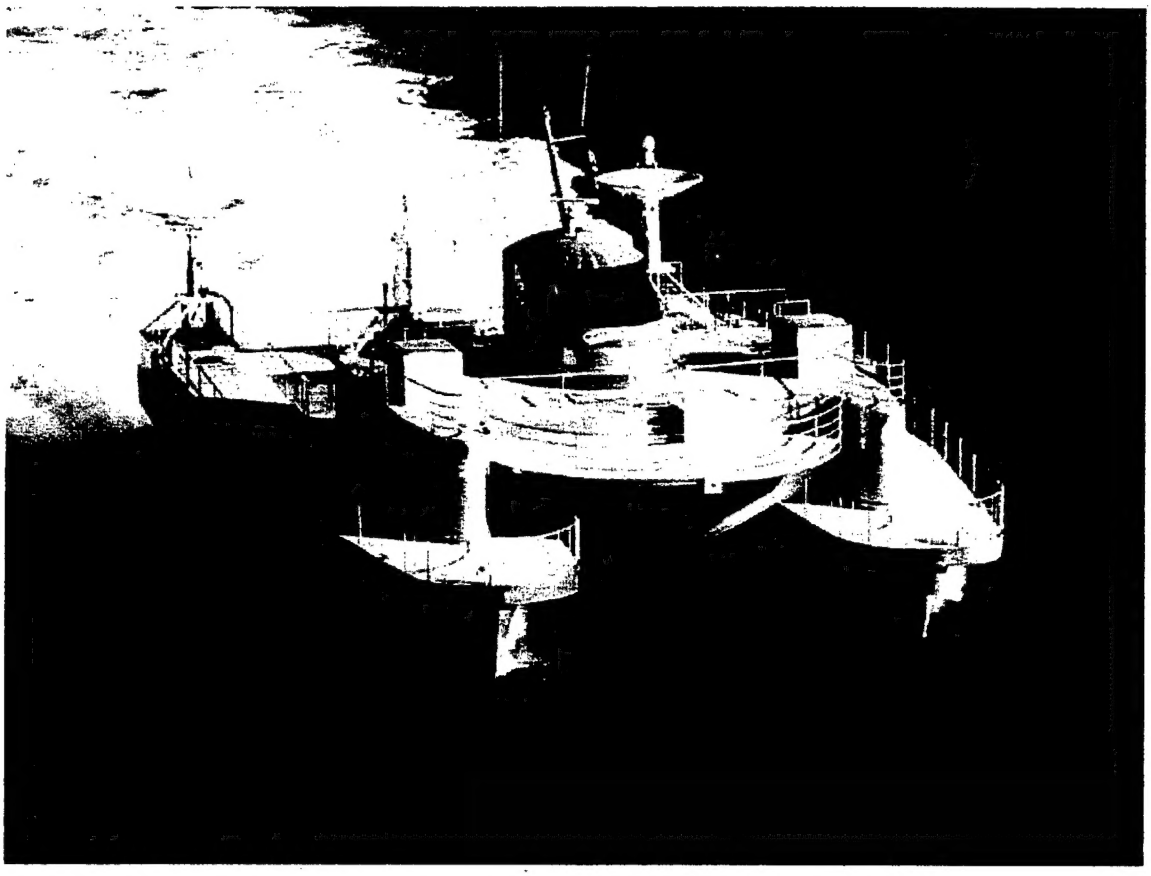
REPORT NO. MIG-SLC-001

AN ASSESSMENT OF SLICE SHIP CONTROL SYSTEM PERFORMANCE



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MYSTIC INNOVATIONS GROUP

Report No. MIG-SLC-001
July 2001

AN ASSESSEMENT OF SLICE SHIP CONTROL SYSTEM PERFORMANCE

Prepared for:
University of Maine

Sponsor: Office of Naval Research

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CONTROL SYSTEMS ANALYSIS AND DESIGN

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20 SECOND TIME CLIP

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1. INTRODUCTION

This report summarizes the effort by Mystic Innovations to review existing documentation and at-sea test results and assess performance of the SLICE ship control system. At-sea data taken by NSWC Carderock (reference a.), Lockheed-Martin (reference b.), and documentation provided by Lockheed-Martin, Pacific Marine, and ONR 362 provided the baseline information to conduct this assessment.

The assessment focused on the SLICE ship control hardware and software entities of the SLICE ship control system consisting of control surfaces, the control surfaces' actuation systems, motion sensors, control computer, control algorithms, and math models/simulations that supported the design and performance predictions.

2. SUMMARY OF PERFORMANCE ANALYSIS

The following summary, conclusions, and suggested direction of future efforts are offered by Mystic Innovations on the limited analysis performed that was constrained by scope and budget.

1. Seakeeping performance improvement with ride control wasn't demonstrated during NSWC at-sea testing. The lack of recording the position command signals to the control surfaces prevented a detailed analysis of control surface actuator performance.

2. Analysis of selected test runs from the Lockheed –Martin at-sea testing effort identified some problem areas.

   a. At the higher speeds, 20-24 knots, oscillatory signals (approximately 2-5 rad/sec) that appear to originate from the roll and pitch sensors result in control surface motions at that period. It is not expected that the actual pitch and roll motions can attain this frequency and therefore it should not be expected that the control surfaces be commanded at these frequencies. The origin of these signals could be structure borne. It is recommended that some aggressive filtering be added to the signal conditioning of the control algorithms.

   b. It is to be noted that there is very little filtering, roll-off attenuation, in the control algorithms. Classical frequency response analysis should be used to determine the required bandwidth of the controller and establish some stability metrics (i.e. gain and phase margin and noise sensitivity).

   c. The at-sea data indicated that the actuation system was not performing well. For the 2-5 rad/sec commands, the actual control surface was lagging the command by as much as 90 degrees. Some malfunctions also seem to occur, in particular, the last "SLICE" run made (Slice_08Nov00_09_57_41) for a ship speed of about 7.5 knots. With the high duty cycle imposed by the earlier 20+ knot runs having the 2-5 rad/sec commands, this might have caused the control surfaces to go out of calibration.

   d. The performance of the control computer hardware indicated a tremendous improvement in reliability. The main objective of Lockheed-Martin has been met. It is understood by Mystic Innovations, that schedule, budget and scope did allow for control algorithm improvement/redesign. With respect to the control surface actuation system the same can be said about improvements there.

3. Suggested Future Efforts

   a. Instrument the control surfaces' actuation systems as Mystic Innovations had suggested previously defining the behavior and limitations of the actuators. Position command and feedback signals are already available. Instrumentation needs to be added to determine, load pressures, servo valve pressure drops, and supply/return pressures for the pumps. It is to be noted that the effects of using the shipboard hydraulic oil (TELLUS 46 –viscosity of 46 Cst @ 104 F) versus the oil that the servo valve flow –gain characteristics were determined with (MIL-H-5606 - viscosity of 13.5 Cst @ 104 F) should be factored into the analysis of the actuation system.

   b. As a result of a. , modify the actuation system to insure positioning errors less than one degree for frequency equal to or less than 1 rad/sec and for positioning rates not to exceed 15 degrees/sec. These are suggested goals.

   c. As a minimum effort, modify the control algorithm by adding filtering to limit the bandwidth of the sensors to minimize the control surface actuation system duty cycle.

3. BACKGROUND

Mystic Innovations Group, Inc. (MIG) under contract from the University of Maine and in support of the Office of Naval Research was initially tasked to assess control issues associated with coupling a trailer vessel to SLICE. SLICE is a Lockheed-Martin experimental vessel that has been based in Hawaii at Pacific Marine facilities for modifications and testing. The Mystic Innovations Group was originally tasked to determine the influence of various hitch concepts upon SLICE and trailer control performance. SLICE Program priorities dictated by ONR 362 redirected MIG support emphasis to the independent review and technical monitoring of the SLICE ship control system upgrade by Lockheed-Martin Baltimore.

This redesign effort was required to improve the reliability of the existing ship control system and that effort primarily addressed system hardware architecture, procurement of hardware, simulation development for laboratory integration testing, documentation, and shipboard installation and testing. Lockheed-Martin's Middle River Division (Baltimore) was tasked to accomplish the redesign and the point-of-contact was Mr. Steven Matelli.

Mystic Innovations' specific efforts from the onset of the tasking were to become familiar with the SLICE concept by reviewing existing documentation, review Lockheed-Martin's design and progress, review sea-keeping data obtained by NSWC, and review the at-sea test data obtained with the redesigned SLICE control system.

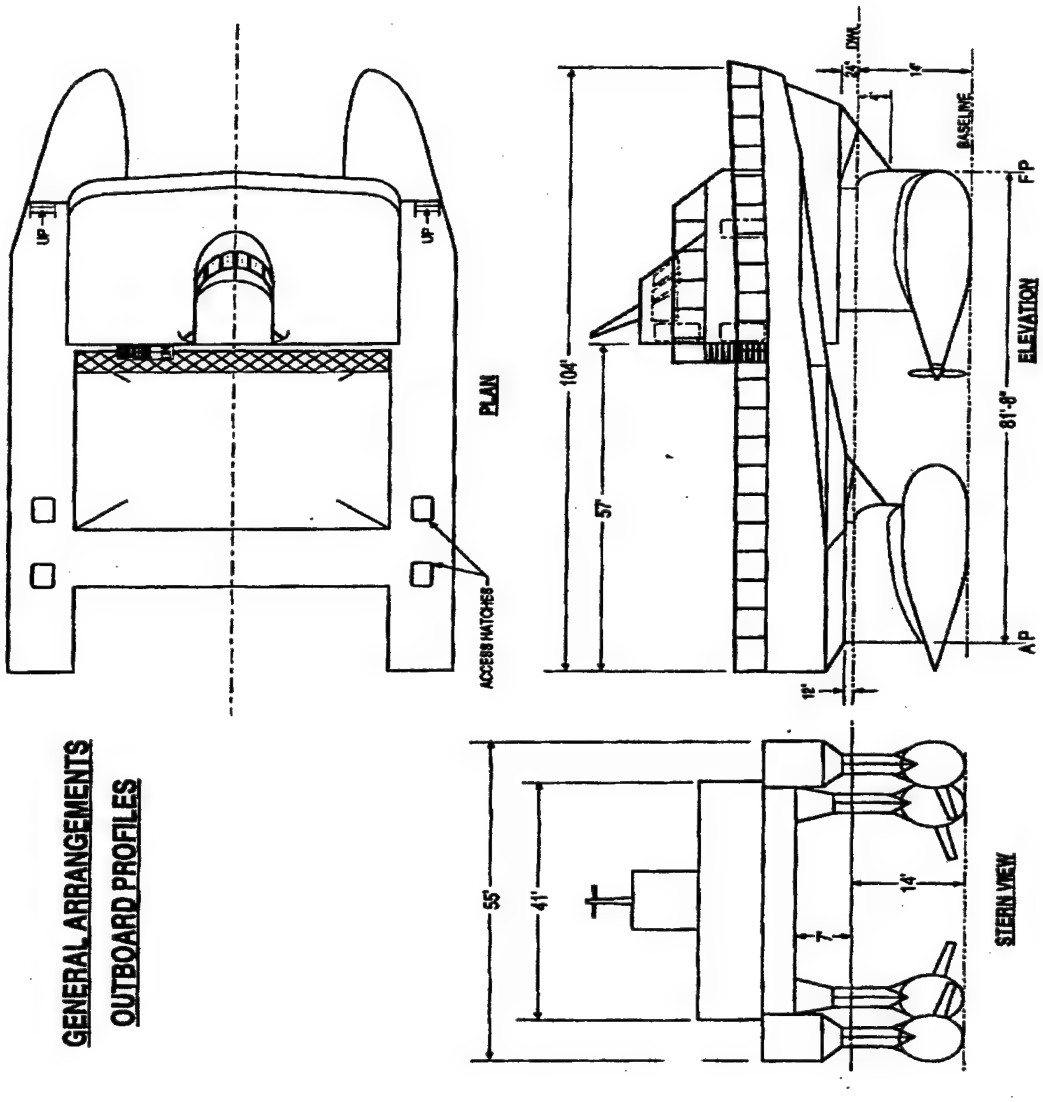
4. COMMENTS ON THE SLICE SHIP

The SLICE ship was evolved from the SWATH concept but with fundamental differences. These differences are 4 small pods instead of 2 long pods and the control surface configuration. Figure 4-1, obtained from reference c, illustrates the pods and the control surface arrangements. It is to be noted that the present SLICE ship is rudderless and reliance of heading changing and course keeping ship control functions are dependant on a 15 degree downward offset from the horizontal plane to generate a yaw moment

If the hydrodynamic characteristics of SLICE were well defined, including the control surfaces, there is the notion that a de-coupling control algorithm can be synthesized that will allow course keeping and changing without a perceptible heeling of the ship. Results to date have not demonstrated this capability or to accomplish a reasonable turning rate (in terms of obstacle avoidance or general maneuvering).

In the opinion of Mystic Innovations Group, while SLICE has accomplished much to demonstrate ship design concepts and the recent upgrade made clear the improvements, remaining deficiencies limit controllability. This report identifies specific deficiencies apparent from the test data and suggest action (see paragraph 2).

FIGURE 4-1


GENERAL ARRANGEMENTS
OUTBOARD PROFILES
PLAN
ACCESS HATCHES
UP
UP
ELEVATION
104'
57'
81'-8"
BASELINE
F P
A P
DWL
24"
14"
12"
STERN VIEW
55'
41'
14'
7'

5. NSWS SEAKEEPING TEST DATA

NSWC Carderock's Seakeeping Department was tasked in March of 1998 by ONR to obtain at-sea data to determine seakeeping ability of SLICE. Reference a. documents the instrumentation onboard, the estimated sea conditions, a summary of test conditions, and post trial data reduction summary. Reference a. presents the results of the testing and post data reduction but does not assess the performance of SLICE Seakeeping.

Mystic Innovations had obtained copies of the data taken for selected conditions that were representative of changes in ship speed, heading, and sea conditions. A brief analysis of the raw data recorded and the summaries in reference a. were conducted to assess SLICE performance.

5.1 Recording Instrumentation

NSWC had provided most of the recorded sensor signals. The additional ship provided signals were ship's pitch, roll, and the control surface commands originating from the ship control computer. Table 1 of reference a. delineates those sensors and units of measurement. The signals from sensors were anti-alias filtered with 2 Hz (12.57 rad/sec) corner frequency filters. Data was recorded at 8 Hz (0.125 samples/second). The anti-aliasing filter breakpoints are sufficiently high enough that the significant frequency response components of the ship and control surfaces will be not be affected.

When the data was processed it was found that the control surface command signals (channels 25 through 28 -Table 1 of reference a.) did not contain any useful data (essentially zero). The absence of data was due to the inability to identify the correct signals on the ship due to inconsistencies between the drawings and the actual ship wiring that was available to NSWC personnel.

5.2 NSWC Results

Table 2 of reference a. delineates the runs that were made and the ship and environmental conditions during those runs. The post processing of the data by NSWC determined the maximum, minimum, and standard deviation of roll, roll rate, pitch, pitch rate, and of the x, y, and z accelerations. Additionally, the mean values of relative wind speed and direction were determined along with the significant wave height. This information was summarized in Tables 3 and 4 of reference a. Table 5 of reference a. delineates the % improvement (- % degradation) of the standard deviations of the ship motions with "Ride Control" relative to without ride control. The results are inconclusive at best with improvement /degradation as random as the sea conditions and heading. It

appears that the ship, in general, is very stable by itself without augmentation by "Ride Control". In general, the roll and pitch motions are small.

5.3 Control Surface Actuation Performance

In order to ascertain why there wasn't significant improvement in sea keeping performance, The control surface position and position rate data was plotted. The position data was post-processed through a rate filter to obtain positioning rate. Appendix A contains the positioning plots of the 4 control surfaces the positioning rates, and the tabular statistical summary of the ship variables provided by NSWC. This data was taken for the ship traveling at an approximate 23 knot speed, oriented in a following sea (estimated to be a high SS-4), and auto "ride control" and manual control. The sea state forces and moments developed by a following sea orientation primarily affect the pitch and heave degrees of freedom. One would expect that the control algorithms that process the sensed pitch and roll motions of the ship to develop command signals to the control surfaces that would attempt to minimize the pitch motions of the ship. It is expected that the commands to the forward control surfaces (port and starboard fins) would each receive the same command signals and the aft pair (port and starboard stabilizers) likewise. The aft and forward pairs would have different commands in accordance with the algorithms' attempt to minimize pitch motion in the auto mode. Unfortunately, the command signals to each of the control surfaces could not be recorded and verification of the expected commands cannot be verified.

Referring to the figures in Appendix A, it is seen that the aft pair control surface (stabilizers) positions are not similar. The starboard control surface excursions (both position and position rate) and the frequency content appear to be reasonable. Conversely the port control surface movement appears to be discontinuous (i.e. port rate). This could be caused by the position data sensor/interface malfunctioning or by the malfunctioning of the control surface positioning control loop hardware. In either case, the aft port control surface position information indicates a malfunction.

Both forward control surfaces are consistent with the aft starboard surface with respect to frequency content and duty cycle. It is observed that the general trend of the forward surfaces are move in opposite directions relative to each other indicating the control surfaces are attempting to minimize roll motions by generating moments that are additive. In a similar way the aft control surfaces have opposite trends with respect to each other (port vs. starboard) and they too generate additive moments. The positioning rates are well within the designed capabilities of the control surface positioning system.

Other test runs were plotted for other ship conditions such as 8 and 15 knot ship speeds, different orientations (beam, quartering ,head seas), and sea states. These results also indicate the aft port control surface malfunctioning. The duty

cycles of the control surfaces were similar as the following sea conditions just discussed.

5.4 Pitch and Roll Sensed Signals

In addition to recording the ship's pitch and roll motions derived from the ship control system sensors, NSWC had provided its own pitch and roll motion sensors for recording. The ship control system roll and pitch sensor signals were provide to NSWC from the pilot house whereas the NSWC sensors were located in the crew's mess. Appendix A contains plots of pitch and roll signals from the NSWC installed sensors and for the Lockheed-Martin (ship control system) derived signals. From the figures, it is seen that the Lockheed-Martin signals have a higher frequency content than the NSWC signals. The higher frequency components in the Lockheed-Martin derived signals can be considered "noise" since it appears to have periods in the range of 1.5 to 3 seconds and not due to ship motions. At 23 knots, the ship's pitch characteristic period is calculated to be approximately 7.5 seconds

A plot of the pitch and roll errors between the two signal sources was made and is contained in Appendix A. It is seen from the plot that the errors are substantial relative to the maximum value of the pitch and roll (approximately +/- 5 deg.) signals for the 30 minute run. In addition to the "noise" content of the Lockheed – Martin signals, phase and magnitude differences between the two signals will be contributing factors as well as coupling effects due to location differences and sensor sensitivity (e.g. cross-talk).

6. SLICE POST CONTROL SYSTEM UPGRADE AT-SEA TESTING

Upon installation and integration testing on SLICE of the upgraded ship control system, at-sea testing was performed to verify improvement in the ship control system functionality and reliability. Reference d is the SLICE Test Plan and Procedures document. Lockheed-Martin provided Mystic Innovations a copy of the recorded data taken during at-sea operations on the 8th and 9th of November 2000. The following is an analysis of selected runs of that data.

6.1 Instrumentation and Recording

As part of the ship control system upgrade, Lockheed-Martin has incorporated software ("Stethoscope") that enables the recording of data directly from the ship control computer to a laptop computer. The data is then archived onto a CD disk. Recorded were the input and output variables of the ship control computer and internal computational variables of the ship control algorithms. Appendix B is a example of the data format file provided by Lockheed-Martin for each data record ("run"). The recorded rate is 5 samples per second as indicated by Appendix B which translates to a recording interval of 0.2 seconds. Most of the "runs" recorded on the 8th of November contained 223 variables with a record size of 1774kbytes which represents approximately 1000 8bit samples per variable.
It is assumed that all data is recorded at the same instant in time and there is no time skew between variables. It is to be noted that some of the data recorded had more or less variables than the format indicated in Appendix B which caused changes in the variables identification index.

6.2 Lockheed-Martin At-Sea Testing Results

Included in Appendix B is the MATLAB program file that was used to "reduce" and plot the data from some selected "runs" of all the data recorded. Plotted were ship speed, pitch, roll, yaw and each of the four control surfaces' command and position, positioning error, command rate and position rate.

Appendix C contains the plots obtained from Lockheed-Martin's record ID "Autoplilot_08_Nov00_12_51_01" and it is the 10th run in the "Autopilot" series. The pitch and roll signals indicate high frequency variations which carry over to the control surfaces' commands and control surfaces' positioning. Although the command excursions are small, the duty cycles of the control surfaces are high. The data was re-plotted for a time slice between 20 to 40 seconds during a period of high control surface activity in order to determine the command signal periods and to ascertain the control surface positioning performance. Appendix D

contains the re-plotted data. The period of high frequency command signals to the control surfaces appears to be between 1.25 to 3.0 seconds. This translates to an approximate frequency range between 2 to 5 rad/sec. The same frequency characteristics can be seen in the pitch and roll (mostly roll) plots and indicates a high sensitivity of the control system to these frequencies and is mainly responsible for the duty cycle of the control surfaces.

Examination of the positioning error plots indicates that the control surface positioning system is unable to follow the commanded signal. It is to be noted that the position signal does contain a bias is likely due to compensations in either the alignment procedure (mechanical versus electrical "zeros") or by trim adjustments made at the helm. Assuming that there is no data skew between the recorded command and position for each control surface and that the sampling period is sufficient, the indication is that there is a significant lag between the input command and the actual control surface position. This lag appears to range between 45 to 90 degrees. Inspection of the plots of command rate of change and the positioning rate show that the rate of actual control surface position is lower in value than the commanded rate and indicates approximately the same phase lag as the command versus position. The implication is that for the frequency range of from 2 to 5 rad/sec, the positioning system is at or beyond its design limits (e.g. bandwidth, rate limit). Section 5.3 of this report discusses the implications of the results.

Appendix E contains plots for Lockheed-Martin run identified as "Slice_08Nov00_09_57_41" . This run was made at a ship speed of approximately 7.5 knots. Examination of the plots reveal several notable characteristics/anomalies. The nature of the command to the control surfaces signals indicates that the Manual Mode was utilized. Inspection of the of the "PilotHouse_autopilotEnabled" flag did not indicate either auto or manual mode. The starboard fin control systems plots shows a positioning failure and is verified by the plot of "Starboard Fin Positioning Error". In general, the positioning error plots for all the control surfaces indicate unacceptable tracking errors while taking into account the know offsets (trim) of the actual control surface position. Course changes were made during this run. A comparison to the "Yaw Angle" plot to the "Roll" angle plot indicates a small influence of a heading change on roll angle.

6.3 Sensor Bandwidth

Two questions arise from the plotted data. What is the origin of the high frequency signals and should the control system respond to these frequencies (2 to 5 rad/sec)? The pitch and roll input signals to the control algorithms are obtained from a "complimentary filter" that combines the signals from a the 2-axis inclinometer (contains "low" frequency pitch and roll positional information) and from a 3 axis angular rate inertial package (roll, pitch and yaw rates) that are pseudo-integrated to produce the "high" frequency positional component of the pitch and roll signals. Figure 6-1 is a block diagram of this filter. The transfer functions and filter break-point information was provided by Lockheed-Martin. The transfer function has a ideal gain of unity and allows all ownship's signals to pass through unattenuated. However, the inertia rate sensor has a roll-off function as well as the dual-axis inclination sensor (AccuStar II). The vendor (Lucas/Schaevitz) data sheet on the sensor indicates a first order roll-off break frequency of 0.5 Hz (-3dB) or 3.14 rad/sec. The roll-off of the inertial rate sensor is expected to be very much higher than the frequencies of interest for SLICE.

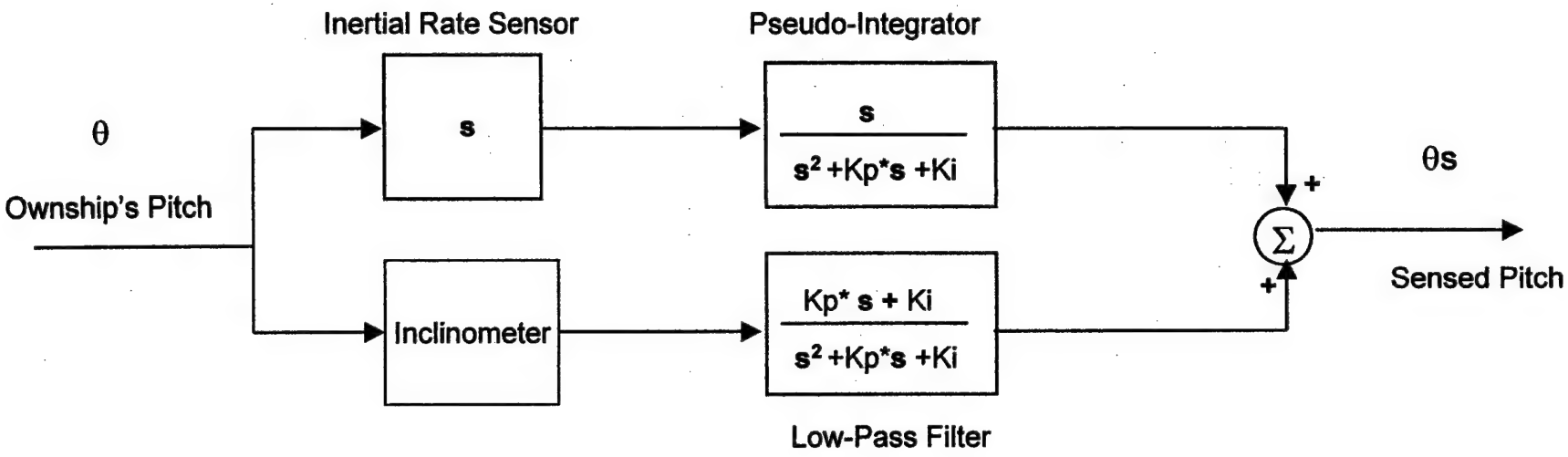
The 2 to 5 rad/sec signals discussed in the previous section can be considered as "noise", since the ship is not expected to respond to these frequencies on the basis of its hydrodynamic characteristics. It recommended that these frequencies be aggressively filtered to enable the control system response to lower frequency disturbances be increased. Discussions with ONR have suggested that the origin of this "noise" is due to ship vibrations, a problem experienced in the past. Aggressive filtering will also help lower the duty cycle of the control surface actuation system.

6.4 Control Surface Actuation System

Mystic Innovations performed some analysis on the SLICE Control Surface Actuation System design. Each control surface has its own hydraulic power source providing hydraulic fluid to a servo valve that controls the fluid flow to a push-pull two cylinder configuration that results in balanced actuator. The actuators drive two tillers (yoke) that provide a balanced rotating torque to the control surface stock (shaft). The hydraulic power source consists of a 60Hz 3-phase induction motor driving a variable displacement piston pump. A the control signal to the servo valve is provided by a PID based off-the shelf controller. The hydraulic oil is Tellus 46 with a viscosity of approximately 30 Cst (139.8 SSU)at 120 deg F. Positional feedback information is provided by LVDT on a actuation cylinder.

The electric motor provides approximately 10hp at its shaft, which means that efficiency and power factor have been accounted for. The shaft speed 1740 rpm at the nominal torque of approximately 364 in-lbs. This is the mechanical input to the hydraulic control system. The hydraulic pump, Parker Model PAVC 38 rated

FIGURE 6-1 LOCKHEED-MARTIN COMPLEMENTARY FILTER
- OWNSHIP'S PITCH EXAMPLE -



where:

$K_i = (\omega_d)^2 = 0.0484$

$K_p = 2*\zeta_d*\omega_d = 0.4400$

$\omega_d = 0.22$ rad/sec

$\zeta = 1.000$

$\text{Gain} = \theta_s(t)/\theta(t) = 1.0$

at 1800 rpm, has a peak power efficiency of 73 % when 10 hp is driving its input shaft. The maximum efficiency is achieved when the load pressure is between 1000 to 1250 psi and the result output flow rate is 12.5 to 10.0 gpm. The pump is a pressure compensated design and will reduce output flow as the load pressure increases. This information was obtained from the Parker data sheet on the pump and the information is based upon Standard Hydraulic Oil having a kinematic viscosity of 100 SSU (20.5 Cst) at 120 deg F. The use of a more viscous oil should improve the volumetric efficiency, however the data sheet indicates that volumetric losses to be approximately 5% at about a 2000 psi load pressure. Using a more viscous oil would increase windage losses, but that is an intuitive assumption not supported by Parker data.
The servo valve is a MOOG Model 35S020 (Standard Series 35) . From the data sheet of the servo valve, The no-load flow can vary from a minimum of 15 gpm to a maximum of 31 gpm for a 1500 psi supply pressure. This data is based upon the hydraulic oil being MIL-H-5606 type. It is assumed that the no-load flow variation is primarily due to variations in oil temperature. MOOG does not provide the rationale for the 2:1 variation in servo valve flows in its data sheet. The effect of different fluid viscosity on servo valve flow gain, TELLUS versus MIL-H-5606, may be best determined by empirical methods or on a broader scale the testing of the control surface positioning system with the TELLUS oil.

The simulation/math model of the control surface actuation system that Lockheed-Martin utilizes in the SLICE control system integration test facility was reviewed and was satisfactory. On the basis of the at-sea testing, the control surface positioning system requires instrumentation and testing. It is necessary to determine load pressure, supply pressure, and pressure drop across the servo valve to revise the math model parameters. The performance of the control surface positioning system has a significant effect upon SLICE ship control design and performance. The intention of Lockheed-Martin during the at-sea testing was to obtain this data and had instrumented the control surfaces' actuation systems. Lockheed-Martin informed Mystic Innovations that problems with the instrumentation did not enable the acquisition of meaningful data. Re-testing was not possible due to schedule and program constraints.

7. REFERENCES

a. "Summary of Seakeeping Trials Aboard SLICE"; Terrence R. Applebee and Dennis A. Woolaver; Navel Surface Warfare Center, Carderock Division; Report Number NSWCCD-50-TR-1999/002; 31 January, 1999

b. "SLICE DATA 11/8-9/2000 – Compact Disk"; Steven Matelli; Lockheed-Martin Launch Systems, Baltimore, MD

c. "Seakeeping Characteristics of SLICE Hulls: A Motion Study in Six Degrees of Freedom"; LT. Donald B. Lesh, USN; Master of Science in Mechanical Engineering; Naval Postgraduate School, Monterey, Ca. ; September,1995

d. "Slice Test Plan and Procedures"; P. Holland; Lockheed-Martin Launching Systems, Baltimore, MD. ; Report No. SLICE SYS 20580200; 3October,2000

APPENDIX A

SLICE SEAKEEPING RUN 60 PLOTS

TRIAL TITLE: SLICE SEA TRIALS JUNE 97
TRIAL NAME: SLICE
TRIAL SUBDIRECTORY SEQ NO: 9
RUN: 60
RUN DATE-TIME-GROUP = 031546Z APR98
COMMENTS: following ctrl on 18 kts 265
SAMPLING INTERVAL = 125 millisec

TOTAL NUMBER OF CHANNELS = 28

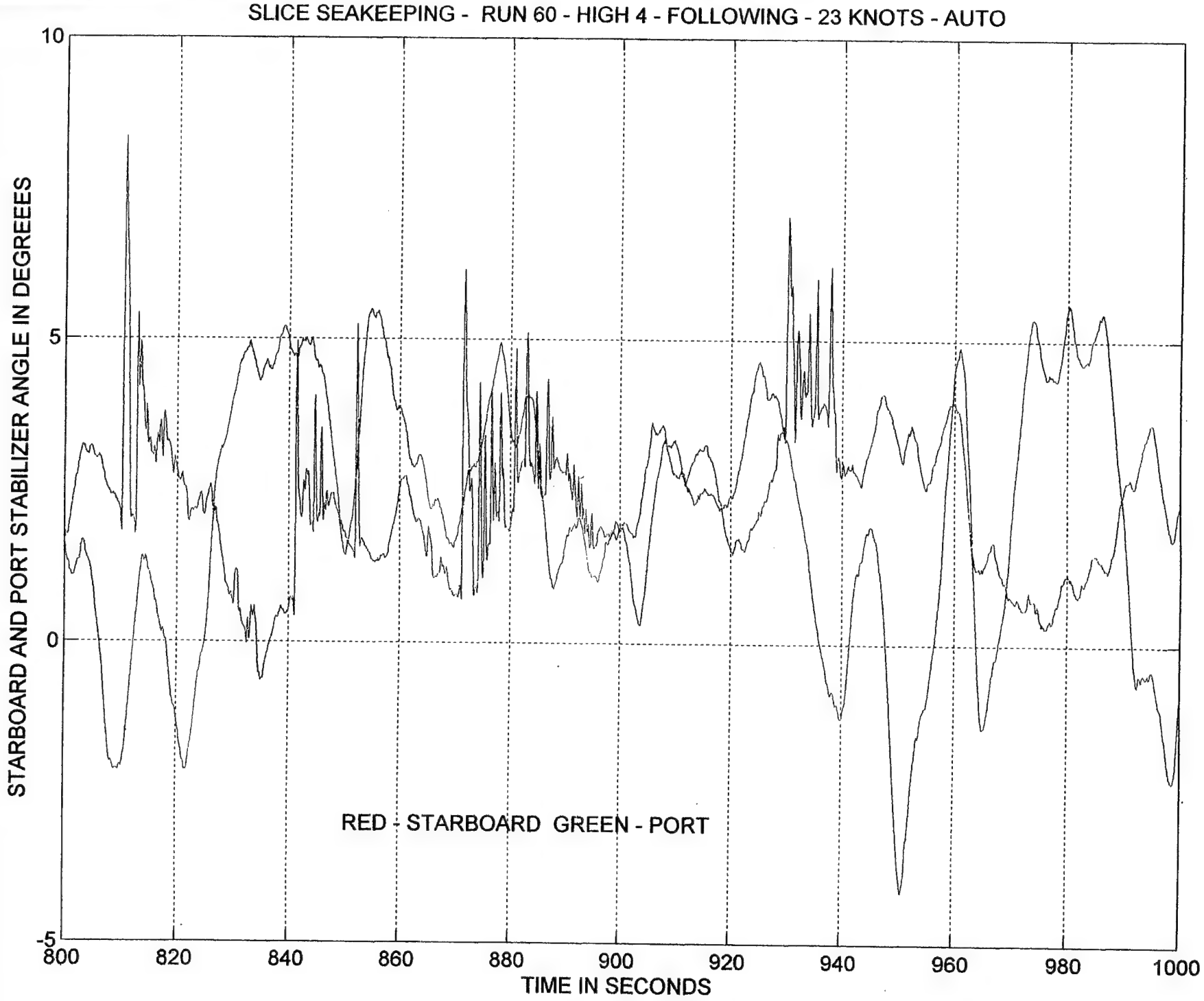
M I N I M U M A N A L Y S I S

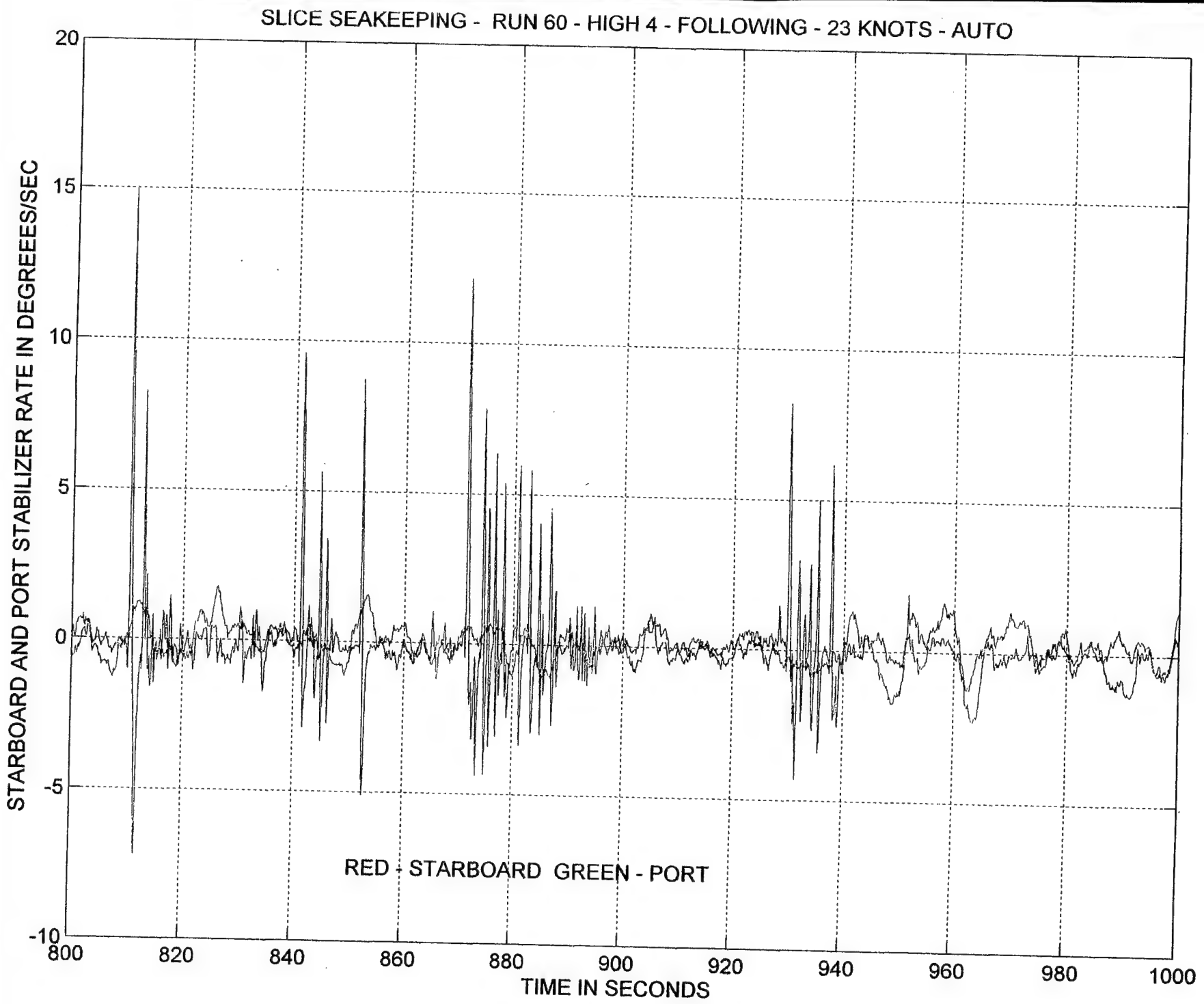
CHAN.	TITLE	UNITS	MEAN	STD. DEV.	MAX	MIN
1	Pitch Angle	deg	-2.398E-01	9.114E-01	3.213E+00	-3.660E+00
2	Roll Angle	deg	9.449E-01	1.113E+00	4.984E+00	-2.474E+00
3	Pitch Rate	Deg/Se	1.241E-01	4.644E-01	2.890E+00	-1.675E+00
4	Roll Rate	deg/se	-1.646E-01	6.331E-01	2.530E+00	-2.205E+00
5	Yaw Rate	g's	-7.306E-02	4.859E-01	1.555E+00	-1.745E+00
6	scsmr vert	g's	6.465E-03	1.393E-02	9.108E-02	-6.527E-02
7	scsmr long	g's	-8.214E-03	2.137E-02	6.160E-02	-1.208E-01
8	scsmr tran	g's	1.969E-03	1.898E-02	8.788E-02	-5.848E-02
9	Remote_Vert	g's	-2.966E-03	1.374E-02	7.565E-02	-6.958E-02
10	Remote_Tran	g's	-1.626E-03	2.039E-02	9.274E-02	-6.665E-02
11	Remote_Long	g's	-2.269E-02	2.456E-02	5.519E-02	-1.482E-01
12	Rel Wind Spd	kts	1.424E+01	2.796E+00	2.395E+01	6.170E+00
13	Rel Wind Dir	deg	6.457E+01	1.164E+01	1.043E+02	2.628E+01
14	TSK Wave Hgt	ft	1.002E-01	2.130E+00	6.463E+00	-8.550E+00
15	TSK Wave Prd	sec	1.957E+01	1.206E+00	2.000E+01	1.316E+01
16	TSK RBM	ft	2.383E-01	2.937E+00	8.528E+00	-1.191E+01
17	TSK Bow Acc	g's	9.334E-03	2.031E-02	1.530E-01	-1.193E-01
18	Stbd Stab	Deg	1.658E+00	2.489E+00	6.952E+00	-7.476E+00
19	Port Stab	Deg	2.436E+00	1.457E+00	1.553E+01	-1.065E+00
20	Stbd Canard	Deg	3.836E+00	2.320E+00	1.089E+01	-4.109E+00
21	Port Canard	Deg	1.788E+00	2.967E+00	1.019E+01	-8.342E+00
22	Heading	deg	2.857E+02	2.532E+00	2.951E+02	2.780E+02
23	Ship Roll	Deg	1.136E+00	1.207E+00	4.802E+00	-3.158E+00
24	Ship Pitch	Deg	-9.434E-02	1.372E+00	4.860E+00	-4.946E+00
25	SShip Aft CS	Deg	3.614E-03	2.955E-03	2.163E-02	-7.750E-03
26	PShip Aft CS	Deg	8.824E-03	3.026E-03	2.713E-02	-3.375E-03
27	SShip Fwd CS	Deg	-2.773E-04	3.172E-03	2.288E-02	-1.500E-02
28	PShip Fwd CS	Deg	2.112E-03	3.233E-03	2.038E-02	-1.263E-02

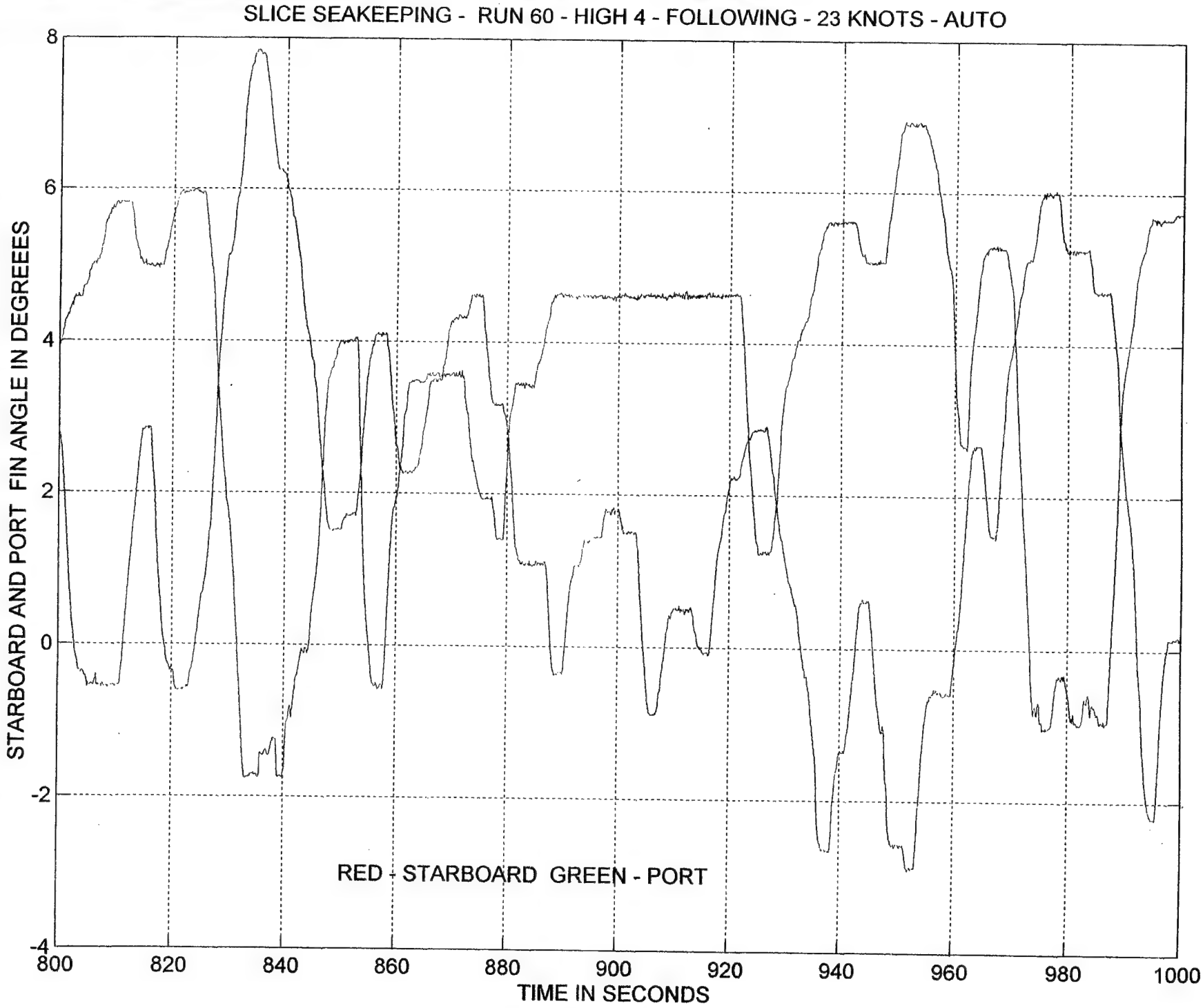
Total number of data records this run = 14401

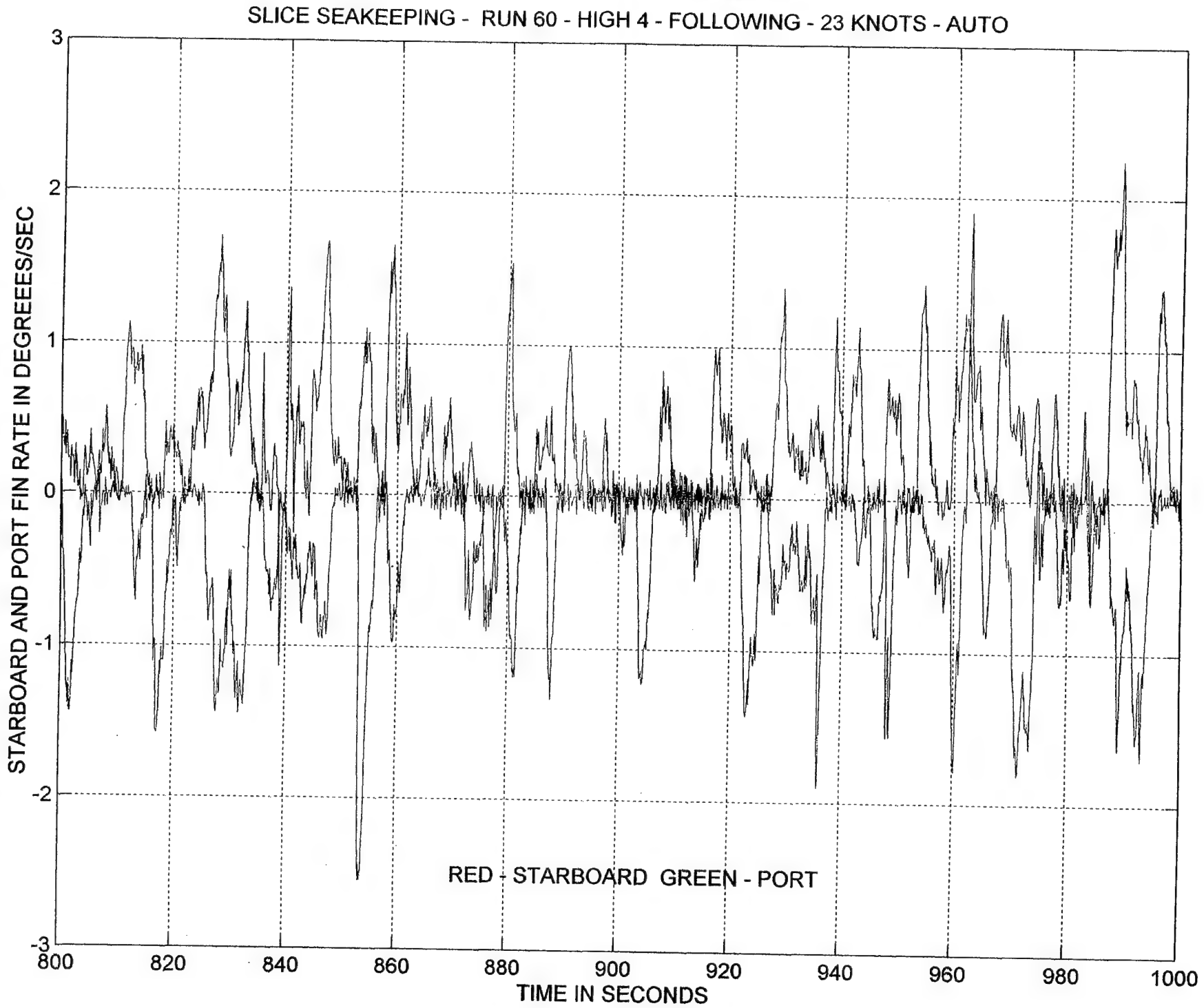
Channels selected for conversion to ASCII format:

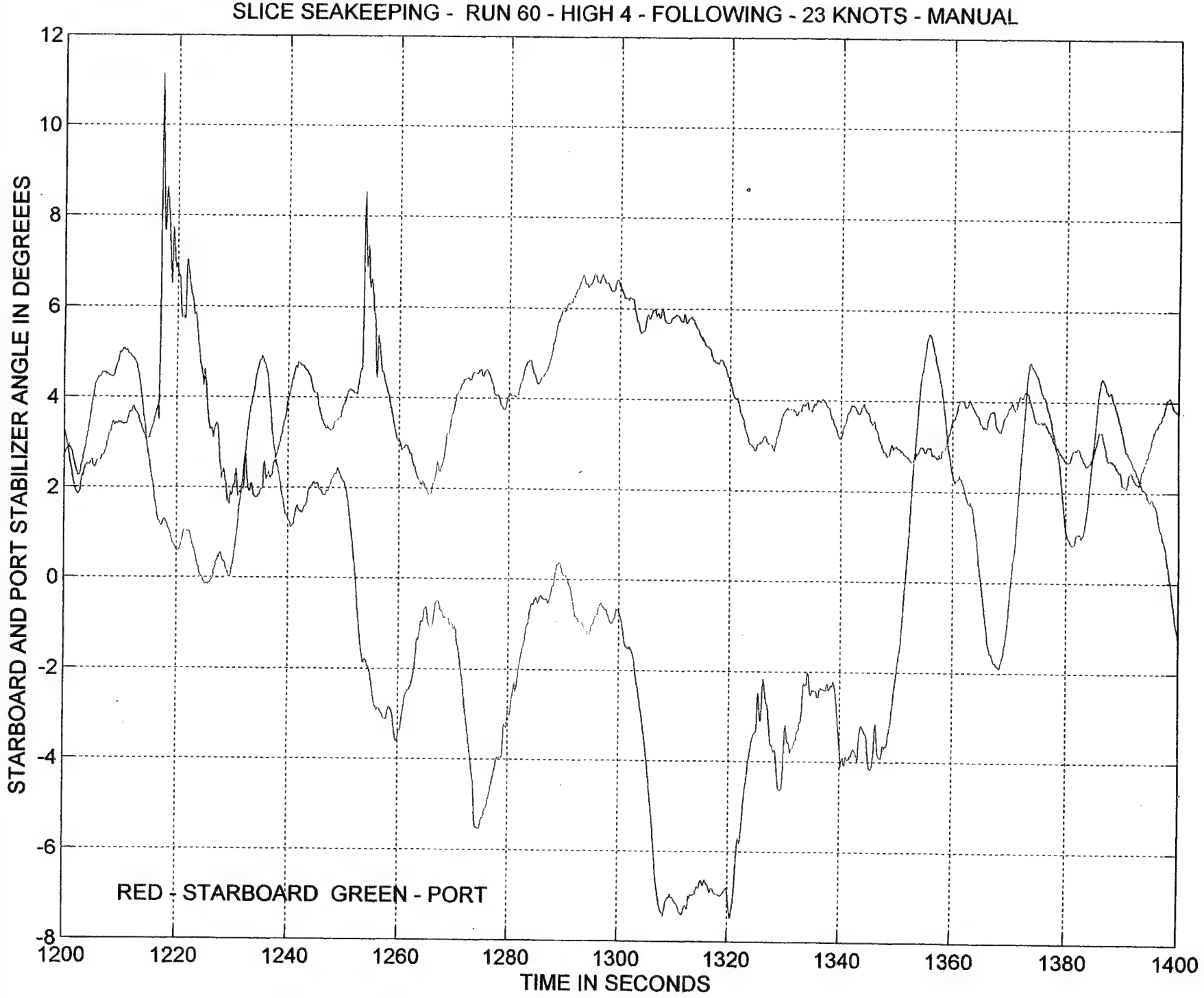
1	Pitch	Angle	12	Rel Wi	nd Spd	23	Ship	Roll
2	Roll	Angle	13	Rel Wi	nd Dir	24	Ship	Pitch
3	Pitch	Rate	14	TSK Wa	ve Hgt	25	SShip	Aft CS
4	Roll	Rate	15	TSK Wa	ve Prd	26	PShip	Aft CS
5	Yaw	Rate	16	TSK	RBM	27	SShip	Fwd CS
6	scsmr	vert	17	TSK Bo	w Acc	28	PShip	Fwd CS
7	scsmr	long	18	Stbd	Stab			
8	scsmr	tran	19	Port	Stab			
9	Remote	_Vert	20	Stbd	Canard			
10	Remote	_Tran	21	Port	Canard			
11	Remote	_Long	22	Headin	g			

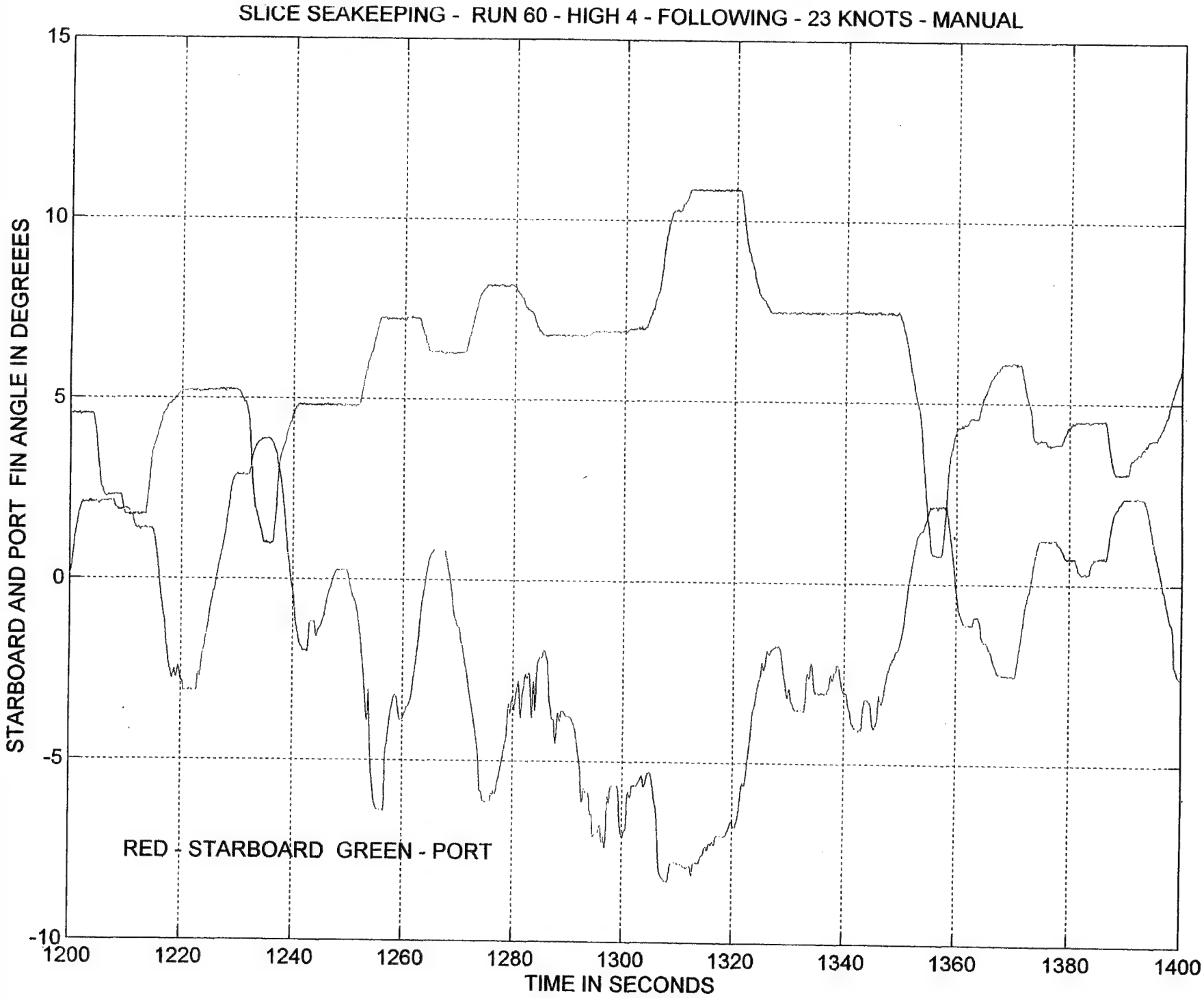

SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - AUTO
STARBOARD AND PORT STABILIZER ANGLE IN DEGREEES
10
5
0
-5
800
820
840
860
880
900
920
940
960
980
1000
TIME IN SECONDS
RED - STARBOARD GREEN - PORT

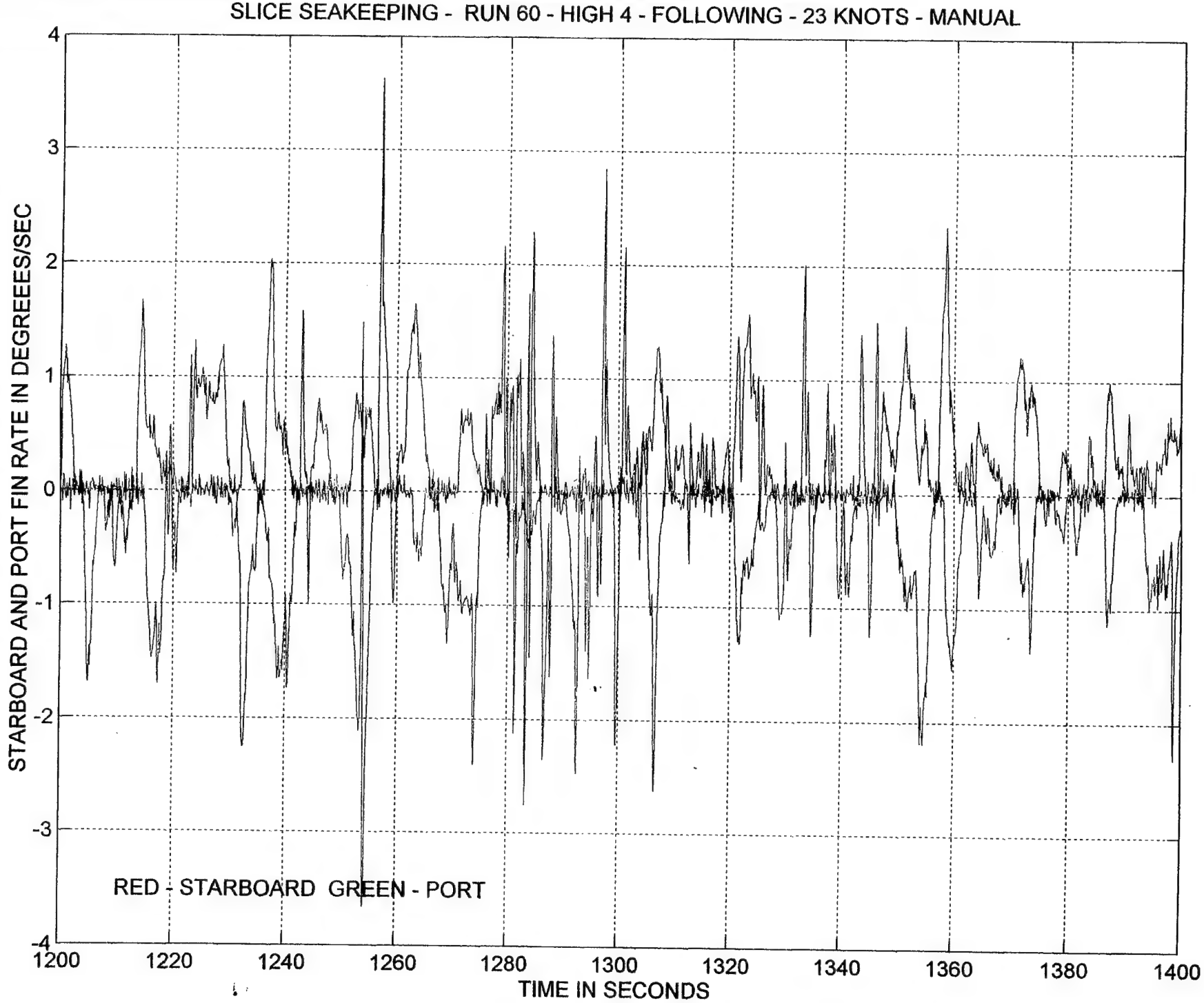

SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - AUTO
STARBOARD AND PORT STABILIZER RATE IN DEGREEES/SEC
20
15
10
5
0
-5
-10
800
820
840
860
880
900
920
940
960
980
1000
TIME IN SECONDS
RED - STARBOARD GREEN - PORT

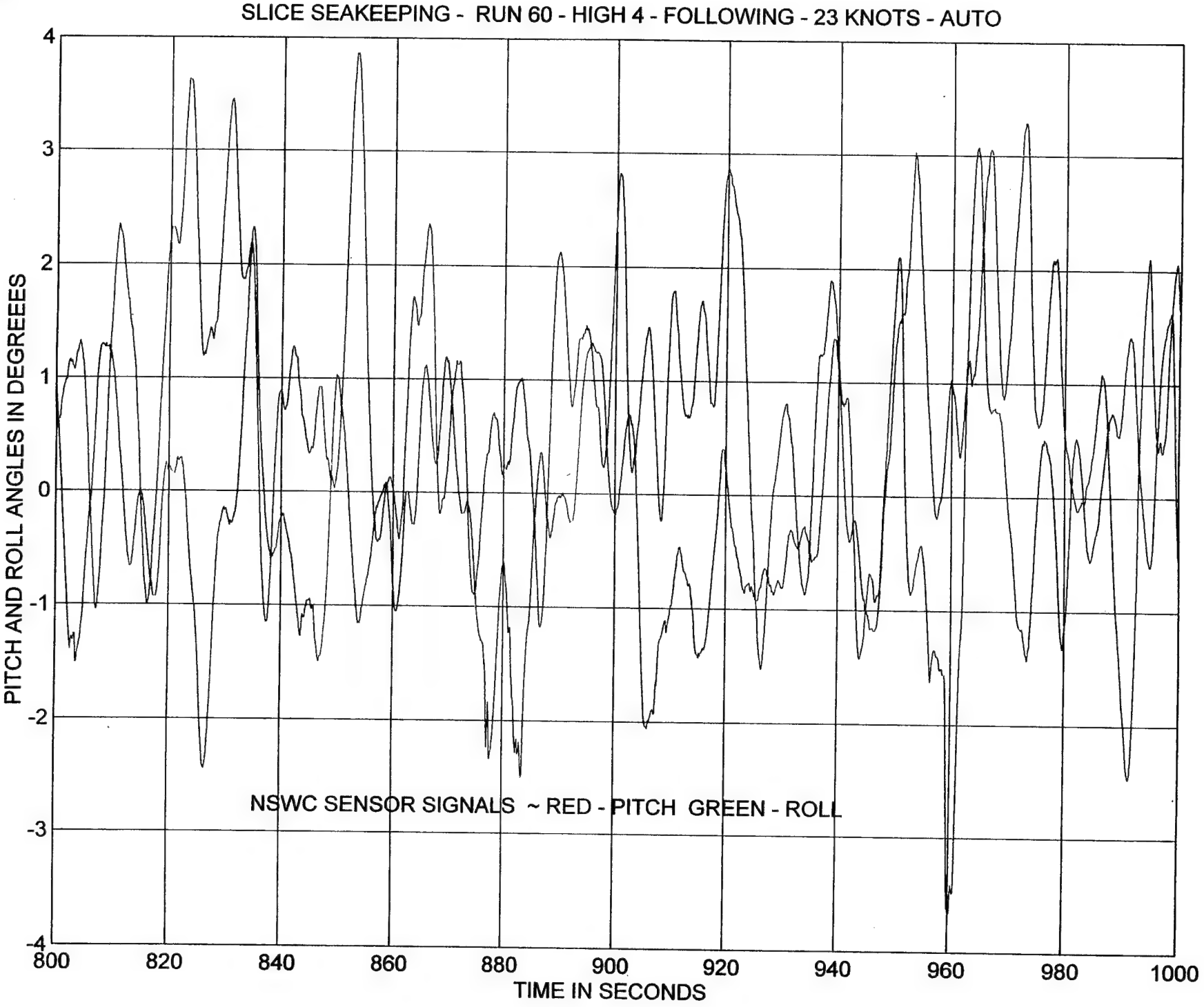

SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - AUTO
STARBOARD AND PORT FIN ANGLE IN DEGREEES
8
6
4
2
0
-2
-4
800
820
840
860
880
900
920
940
960
980
1000
TIME IN SECONDS
RED - STARBOARD GREEN - PORT


SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - AUTO
STARBOARD AND PORT FIN RATE IN DEGREEES/SEC
3
2
1
0
-1
-2
-3
800
820
840
860
880
900
920
940
960
980
1000
TIME IN SECONDS
RED - STARBOARD GREEN - PORT


SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - MANUAL
STARBOARD AND PORT STABILIZER ANGLE IN DEGREES
12
10
8
6
4
2
0
-2
-4
-6
-8
1200
1220
1240
1260
1280
1300
1320
1340
1360
1380
1400
TIME IN SECONDS
RED - STARBOARD GREEN - PORT


SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - MANUAL
STARBOARD AND PORT FIN ANGLE IN DEGREEES
15
10
5
0
-5
-10
1200
1220
1240
1260
1280
1300
1320
1340
1360
1380
1400
TIME IN SECONDS
RED - STARBOARD GREEN - PORT


SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - MANUAL
STARBOARD AND PORT FIN RATE IN DEGREEES/SEC
TIME IN SECONDS
RED - STARBOARD GREEN - PORT
4
3
2
1
0
-1
-2
-3
-4
1200
1220
1240
1260
1280
1300
1320
1340
1360
1380
1400


SLICE SEAKEEPING - RUN 60 - HIGH 4 - FOLLOWING - 23 KNOTS - AUTO
PITCH AND ROLL ANGLES IN DEGREEES
4
3
2
1
0
-1
-2
-3
-4
800
820
840
860
880
900
920
940
960
980
1000
TIME IN SECONDS
NSWC SENSOR SIGNALS ~ RED - PITCH GREEN - ROLL

APPENDIX B

LMC-BALTIMORE RECORDED DATA FORMAT

AND

MATLAB PLOT FORMATING

LMC-BALTIMORE RECORDED DATA

```
load Slice_08Nov00_09_57_41.mat;
data = data';
[numberOfSamples numberOfSignals] = size(data);
filename = ['e:\Mat/Slice_08Nov00_09_57_41'];
runtitle = ['Unnamed'];
notes = [
'Session Notes:'
];
notes
buffernotes = [
'Buffer notes:'
];
buffernotes
SampleRate = 5.000000;
SampleDivisor = 1;
MainEng_stbd_engineOnIndicator = data(:,1);
MainEng_stbd_overspeedAlert = data(:,2);
MainEng_stbd_coldNoClutch = data(:,3);
MainEng_stbd_localControl = data(:,4);
MainEng_stbd_lopPowerSupplyFailure = data(:,5);
MainEng_stbd_lopFailure = data(:,6);
MainEng_stbd_lowCoolantLevel = data(:,7);
MainEng_stbd_fuelLeak = data(:,8);
MainEng_stbd_oilPressureShutdown = data(:,9);
MainEng_stbd_airFlapShutdown = data(:,10);
MainEng_stbd_fuelSupplyFilterPressureDeltaP = data(:,11);
MainEng_stbd_lubeOilPressure = data(:,12);
MainEng_stbd_controlAirPressure = data(:,13);
MainEng_stbd_exhaustPortATemp = data(:,14);
MainEng_stbd_exhaustPortBTemp = data(:,15);
MainEng_stbd_coolantPressure = data(:,16);
MainEng_stbd_coolantTemperature = data(:,17);
MainEng_stbd_fuelRackSetting = data(:,18);
MainEng_stbd_engineRPM = data(:,19);
MainEng_stbd_chargeAirPressure = data(:,20);
MainEng_stbd_saltWaterCoolingPressure = data(:,21);
MainEng_stbd_fuelPressure = data(:,22);
MainEng_stbd_engineShutdownCmd = data(:,23);
MainEng_port_engineOnIndicator = data(:,24);
MainEng_port_overspeedAlert = data(:,25);
MainEng_port_coldNoClutch = data(:,26);
MainEng_port_localControl = data(:,27);
MainEng_port_lopPowerSupplyFailure = data(:,28);
MainEng_port_lopFailure = data(:,29);
MainEng_port_lowCoolantLevel = data(:,30);
MainEng_port_fuelLeak = data(:,31);
MainEng_port_oilPressureShutdown = data(:,32);
MainEng_port_airFlapShutdown = data(:,33);
MainEng_port_fuelSupplyFilterPressureDeltaP = data(:,34);
MainEng_port_lubeOilPressure = data(:,35);
MainEng_port_controlAirPressure = data(:,36);
MainEng_port_exhaustPortATemp = data(:,37);
MainEng_port_exhaustPortBTemp = data(:,38);
MainEng_port_coolantPressure = data(:,39);
MainEng_port_coolantTemperature = data(:,40);
MainEng_port_fuelRackSetting = data(:,41);
MainEng_port_engineRPM = data(:,42);
```

```
MainEng_port_chargeAirPressure = data(:,43);
MainEng_port_saltWaterCoolingPressure = data(:,44);
MainEng_port_fuelPressure = data(:,45);
MainEng_port_engineShutdownCmd = data(:,46);
CPP_stbd_powerFailure = data(:,47);
CPP_stbd_controlFailure = data(:,48);
CPP_stbd_lowHydLev = data(:,49);
CPP_stbd_sternTubeLubeLow = data(:,50);
CPP_stbd_sternTubeCoolantFlow = data(:,51);
CPP_stbd_cloggedHydFilt = data(:,52);
CPP_stbd_hydOilTempHi = data(:,53);
CPP_stbd_lowHydPres = data(:,54);
CPP_stbd_odBoxTemp = data(:,55);
CPP_stbd_cppStBearingTempC = data(:,56);
CPP_port_powerFailure = data(:,57);
CPP_port_controlFailure = data(:,58);
CPP_port_lowHydLev = data(:,59);
CPP_port_sternTubeLubeLow = data(:,60);
CPP_port_sternTubeCoolantFlow = data(:,61);
CPP_port_cloggedHydFilt = data(:,62);
CPP_port_hydOilTempHi = data(:,63);
CPP_port_lowHydPres = data(:,64);
CPP_port_odBoxTemp = data(:,65);
CPP_port_cppStBearingTempC = data(:,66);
Fin_stbd_canard = data(:,67);
Fin_port_canard = data(:,68);
Fin_stbd_stabil = data(:,69);
Fin_port_stabil = data(:,70);
Fuel_stbd_fuelPumpOn_out = data(:,71);
Fuel_stbd_fuelPumpPres = data(:,72);
Fuel_stbd_SwgPSI = data(:,73);
Fuel_stbd_SwgLevGal = data(:,74);
Fuel_stbd_SwgLevFt = data(:,75);
Fuel_stbd_DgLevPSI = data(:,76);
Fuel_stbd_DgLevGal = data(:,77);
Fuel_stbd_DgLevFt = data(:,78);
Fuel_stbd_FwdLevPSI = data(:,79);
Fuel_stbd_FwdLevGal = data(:,80);
Fuel_stbd_FwdLevFt = data(:,81);
Fuel_port_fuelPumpOn_out = data(:,82);
Fuel_port_fuelPumpPres = data(:,83);
Fuel_port_SwgPSI = data(:,84);
Fuel_port_SwgLevGal = data(:,85);
Fuel_port_SwgLevFt = data(:,86);
Fuel_port_DgLevPSI = data(:,87);
Fuel_port_DgLevGal = data(:,88);
Fuel_port_DgLevFt = data(:,89);
Fuel_port_FwdLevPSI = data(:,90);
Fuel_port_FwdLevGal = data(:,91);
Fuel_port_FwdLevFt = data(:,92);
PilotHouse_apPortAdjust = data(:,93);
PilotHouse_apStbdAdjust = data(:,94);
PilotHouse_apEnable = data(:,95);
PilotHouse_courseLockCmd = data(:,96);
PilotHouse_helmCall = data(:,97);
PilotHouse_autopilotEnabled = data(:,98);
PilotHouse_coursePort = data(:,99);
```

```
PilotHouse_courseStbd = data(:,100);
PilotHouse_courseLockInd = data(:,101);
PilotHouse_helm = data(:,102);
PilotHouse_pitchJoystick = data(:,103);
PilotHouse_rollJoystick = data(:,104);
PilotHouse_portCppRpm = data(:,105);
PilotHouse_portCppPitch = data(:,106);
PilotHouse_stbdCppRpm = data(:,107);
PilotHouse_stbdCppPitch = data(:,108);
PilotHouse_neutralPressure = data(:,109);
PilotHouse_pitotPressure = data(:,110);
Motion_SpeedLog_speedKnots = data(:,111);
Motion_SpeedLog_speedKilometers = data(:,112);
Motion_SpeedLog_speedFromPropStbd = data(:,113);
Motion_SpeedLog_speedFromPropPort = data(:,114);
Motion_SpeedLog_depthFathoms = data(:,115);
Motion_SpeedLog_depthMeters = data(:,116);
Motion_SpeedLog_depthFeet = data(:,117);
Motion_SpeedLog_tempCelsius = data(:,118);
Motion_Rates_pitch = data(:,119);
Motion_Rates_pitchRate = data(:,120);
Motion_Rates_roll = data(:,121);
Motion_Rates_rollRate = data(:,122);
Motion_Rates_yaw = data(:,123);
Motion_Rates_yawRate = data(:,124);
Motion_Rates_yawFiltered = data(:,125);
Motion_PIDGains_prop_roll = data(:,126);
Motion_PIDGains_prop_pitch = data(:,127);
Motion_PIDGains_prop_yaw = data(:,128);
Motion_PIDGains_integ_roll = data(:,129);
Motion_PIDGains_integ_pitch = data(:,130);
Motion_PIDGains_integ_yaw = data(:,131);
Motion_PIDGains_diff_roll = data(:,132);
Motion_PIDGains_diff_pitch = data(:,133);
Motion_PIDGains_diff_yaw = data(:,134);
Motion_BiasDSA_fin_dist_roll = data(:,135);
Motion_BiasDSA_fin_dist_pitch = data(:,136);
Motion_BiasDSA_fin_dist_yaw = data(:,137);
Motion_BiasDSA_roll_yaw_coupling = data(:,138);
Motion_BiasDSA_fin_offset_canard_stbd = data(:,139);
Motion_BiasDSA_fin_offset_canard_port = data(:,140);
Motion_BiasDSA_fin_offset_stab_stbd = data(:,141);
Motion_BiasDSA_fin_offset_stab_port = data(:,142);
Motion_SetPt_roll = data(:,143);
Motion_SetPt_pitch = data(:,144);
Motion_SetPt_roll_gui = data(:,145);
Motion_SetPt_pitch_gui = data(:,146);
Motion_SetPt_roll_joystick = data(:,147);
Motion_SetPt_pitch_joystick = data(:,148);
Motion_autopilotHeading = data(:,149);
Motion_Override_canard_stbd = data(:,150);
Motion_Override_canard_port = data(:,151);
Motion_Override_stab_stbd = data(:,152);
Motion_Override_stab_port = data(:,153);
Motion_Override_controller_state = data(:,154);
Motion_FinCmd_stbd_canard = data(:,155);
Motion_FinCmd_port_canard = data(:,156);
```

```
Motion_FinCmd_stbd_stabil = data(:,157);
Motion_FinCmd_port_stabil = data(:,158);
Motion_motionControlState = data(:,159);
Motion_stall_angle_1_speed = data(:,160);
Motion_stall_angle_2_speed = data(:,161);
Motion_stall_angle_3_speed = data(:,162);
Motion_stall_angle_1_canard = data(:,163);
Motion_stall_angle_2_canard = data(:,164);
Motion_stall_angle_3_canard = data(:,165);
Motion_stall_angle_1_stab = data(:,166);
Motion_stall_angle_2_stab = data(:,167);
Motion_stall_angle_3_stab = data(:,168);
Algo_H_gainKp = data(:,169);
Algo_H_desMotBef = data(:,170);
Algo_R_motErr = data(:,171);
Algo_R_int1 = data(:,172);
Algo_R_int2 = data(:,173);
Algo_R_filtered = data(:,174);
Algo_R_setptErr = data(:,175);
Algo_R_intPID = data(:,176);
Algo_R_desired = data(:,177);
Algo_P_motErr = data(:,178);
Algo_P_int1 = data(:,179);
Algo_P_int2 = data(:,180);
Algo_P_filtered = data(:,181);
Algo_P_setptErr = data(:,182);
Algo_P_intPID = data(:,183);
Algo_P_desired = data(:,184);
Algo_H_motErr = data(:,185);
Algo_H_int1 = data(:,186);
Algo_H_int2 = data(:,187);
Algo_H_filtered = data(:,188);
Algo_H_setptErr = data(:,189);
Algo_H_intPID = data(:,190);
Algo_H_desired = data(:,191);
Algo_AP_APHead = data(:,192);
Algo_AP_compHead = data(:,193);
Algo_AP_compHeadFilt = data(:,194);
Algo_A_speed = data(:,195);
Algo_A_AvgSpeed = data(:,196);
Algo_Fins_Raw_PC = data(:,197);
Algo_Fins_Raw_SC = data(:,198);
Algo_Fins_Raw_PS = data(:,199);
Algo_Fins_Raw_SS = data(:,200);
Algo_Fins_Gain_PC = data(:,201);
Algo_Fins_Gain_SC = data(:,202);
Algo_Fins_Gain_PS = data(:,203);
Algo_Fins_Gain_SS = data(:,204);
Algo_Fins_Offset_PC = data(:,205);
Algo_Fins_Offset_SC = data(:,206);
Algo_Fins_Offset_PS = data(:,207);
Algo_Fins_Offset_SS = data(:,208);
Algo_Fins_Delta_PC = data(:,209);
Algo_Fins_Delta_SC = data(:,210);
Algo_Fins_Delta_PS = data(:,211);
Algo_Fins_Delta_SS = data(:,212);
Algo_Fins_Cmd_PC = data(:,213);
```

LMC-BALTIMORE RECORDED DATA

```
Algo_Fins_Cmd_SC = data(:,214);
Algo_Fins_Cmd_PS = data(:,215);
Algo_Fins_Cmd_SS = data(:,216);
Algo_Fins_CmdNoOff_PC = data(:,217);
Algo_Fins_CmdNoOff_SC = data(:,218);
Algo_Fins_CmdNoOff_PS = data(:,219);
Algo_Fins_CmdNoOff_SS = data(:,220);
Algo_Flags_LowSpeeds = data(:,221);
Algo_Flags_FastYawRate = data(:,222);
Algo_Flags_FinOffsets = data(:,223);
time = 0.0:0.200000:0.200000 * (numberOfSamples - 0.5 );
names = [
'MainEng/stbd/engineOnIndicator                '
'MainEng/stbd/overspeedAlert                   '
'MainEng/stbd/coldNoClutch                     '
'MainEng/stbd/localControl                     '
'MainEng/stbd/lopPowerSupplyFailure            '
'MainEng/stbd/lopFailure                       '
'MainEng/stbd/lowCoolantLevel                  '
'MainEng/stbd/fuelLeak                         '
'MainEng/stbd/oilPressureShutdown              '
'MainEng/stbd/airFlapShutdown                  '
'MainEng/stbd/fuelSupplyFilterPressureDeltaP'
'MainEng/stbd/lubeOilPressure                  '
'MainEng/stbd/controlAirPressure               '
'MainEng/stbd/exhaustPortATemp                 '
'MainEng/stbd/exhaustPortBTemp                 '
'MainEng/stbd/coolantPressure                  '
'MainEng/stbd/coolantTemperature               '
'MainEng/stbd/fuelRackSetting                  '
'MainEng/stbd/engineRPM                        '
'MainEng/stbd/chargeAirPressure                '
'MainEng/stbd/saltWaterCoolingPressure         '
'MainEng/stbd/fuelPressure                     '
'MainEng/stbd/engineShutdownCmd                '
'MainEng/port/engineOnIndicator                '
'MainEng/port/overspeedAlert                   '
'MainEng/port/coldNoClutch                     '
'MainEng/port/localControl                     '
'MainEng/port/lopPowerSupplyFailure            '
'MainEng/port/lopFailure                       '
'MainEng/port/lowCoolantLevel                  '
'MainEng/port/fuelLeak                         '
'MainEng/port/oilPressureShutdown              '
'MainEng/port/airFlapShutdown                  '
'MainEng/port/fuelSupplyFilterPressureDeltaP'
'MainEng/port/lubeOilPressure                  '
'MainEng/port/controlAirPressure               '
'MainEng/port/exhaustPortATemp                 '
'MainEng/port/exhaustPortBTemp                 '
'MainEng/port/coolantPressure                  '
'MainEng/port/coolantTemperature               '
'MainEng/port/fuelRackSetting                  '
'MainEng/port/engineRPM                        '
'MainEng/port/chargeAirPressure                '
'MainEng/port/saltWaterCoolingPressure         '
'MainEng/port/fuelPressure                     '
```

LMC-BALTIMORE RECORDED DATA

'MainEng/port/engineShutdownCmd '
'CPP/stbd/powerFailure '
'CPP/stbd/controlFailure '
'CPP/stbd/lowHydLev '
'CPP/stbd/sternTubeLubeLow '
'CPP/stbd/sternTubeCoolantFlow '
'CPP/stbd/cloggedHydFilt '
'CPP/stbd/hydOilTempHi '
'CPP/stbd/lowHydPres '
'CPP/stbd/odBoxTemp '
'CPP/stbd/cppStBearingTempC '
'CPP/port/powerFailure '
'CPP/port/controlFailure '
'CPP/port/lowHydLev '
'CPP/port/sternTubeLubeLow '
'CPP/port/sternTubeCoolantFlow '
'CPP/port/cloggedHydFilt '
'CPP/port/hydOilTempHi '
'CPP/port/lowHydPres '
'CPP/port/odBoxTemp '
'CPP/port/cppStBearingTempC '
'Fin/stbd_canard '
'Fin/port_canard '
'Fin/stbd_stabil '
'Fin/port_stabil '
'Fuel/stbd/fuelPumpOn-out '
'Fuel/stbd/fuelPumpPres '
'Fuel/stbd/SwgPSI '
'Fuel/stbd/SwgLevGal '
'Fuel/stbd/SwgLevFt '
'Fuel/stbd/DgLevPSI '
'Fuel/stbd/DgLevGal '
'Fuel/stbd/DgLevFt '
'Fuel/stbd/FwdLevPSI '
'Fuel/stbd/FwdLevGal '
'Fuel/stbd/FwdLevFt '
'Fuel/port/fuelPumpOn-out '
'Fuel/port/fuelPumpPres '
'Fuel/port/SwgPSI '
'Fuel/port/SwgLevGal '
'Fuel/port/SwgLevFt '
'Fuel/port/DgLevPSI '
'Fuel/port/DgLevGal '
'Fuel/port/DgLevFt '
'Fuel/port/FwdLevPSI '
'Fuel/port/FwdLevGal '
'Fuel/port/FwdLevFt '
'PilotHouse/apPortAdjust '
'PilotHouse/apStbdAdjust '
'PilotHouse/apEnable '
'PilotHouse/courseLockCmd '
'PilotHouse/helmCall '
'PilotHouse/autopilotEnabled '
'PilotHouse/coursePort '
'PilotHouse/courseStbd '
'PilotHouse/courseLockInd '
'PilotHouse/helm '

LMC-BALTIMORE RECORDED DATA

'PilotHouse/pitchJoystick '
'PilotHouse/rollJoystick '
'PilotHouse/portCppRpm '
'PilotHouse/portCppPitch '
'PilotHouse/stbdCppRpm '
'PilotHouse/stbdCppPitch '
'PilotHouse/neutralPressure '
'PilotHouse/pitotPressure '
'Motion/SpeedLog/speedKnots '
'Motion/SpeedLog/speedKilometers '
'Motion/SpeedLog/speedFromPropStbd '
'Motion/SpeedLog/speedFromPropPort '
'Motion/SpeedLog/depthFathoms '
'Motion/SpeedLog/depthMeters '
'Motion/SpeedLog/depthFeet '
'Motion/SpeedLog/tempCelsius '
'Motion/Rates/pitch '
'Motion/Rates/pitchRate '
'Motion/Rates/roll '
'Motion/Rates/rollRate '
'Motion/Rates/yaw '
'Motion/Rates/yawRate '
'Motion/Rates/yawFiltered '
'Motion/PIDGains/prop_roll '
'Motion/PIDGains/prop_pitch '
'Motion/PIDGains/prop_yaw '
'Motion/PIDGains/integ_roll '
'Motion/PIDGains/integ_pitch '
'Motion/PIDGains/integ_yaw '
'Motion/PIDGains/diff_roll '
'Motion/PIDGains/diff_pitch '
'Motion/PIDGains/diff_yaw '
'Motion/BiasDSA/fin_dist_roll '
'Motion/BiasDSA/fin_dist_pitch '
'Motion/BiasDSA/fin_dist_yaw '
'Motion/BiasDSA/roll_yaw_coupling '
'Motion/BiasDSA/fin_offset_canard_stbd '
'Motion/BiasDSA/fin_offset_canard_port '
'Motion/BiasDSA/fin_offset_stab_stbd '
'Motion/BiasDSA/fin_offset_stab_port '
'Motion/SetPt/roll '
'Motion/SetPt/pitch '
'Motion/SetPt/roll_gui '
'Motion/SetPt/pitch_gui '
'Motion/SetPt/roll_joystick '
'Motion/SetPt/pitch_joystick '
'Motion/autopilotHeading '
'Motion/Override/canard_stbd '
'Motion/Override/canard_port '
'Motion/Override/stab_stbd '
'Motion/Override/stab_port '
'Motion/Override/controller_state '
'Motion/FinCmd/stbd_canard '
'Motion/FinCmd/port_canard '
'Motion/FinCmd/stbd_stabil '
'Motion/FinCmd/port_stabil '
'Motion/motionControlState '

LMC-BALTIMORE RECORDED DATA

'Motion/stall_angle_1_speed '
'Motion/stall_angle_2_speed '
'Motion/stall_angle_3_speed '
'Motion/stall_angle_1_canard '
'Motion/stall_angle_2_canard '
'Motion/stall_angle_3_canard '
'Motion/stall_angle_1_stab '
'Motion/stall_angle_2_stab '
'Motion/stall_angle_3_stab '
'Algo/H/gainKp '
'Algo/H/desMotBef '
'Algo/R/motErr '
'Algo/R/int1 '
'Algo/R/int2 '
'Algo/R/filtered '
'Algo/R/setptErr '
'Algo/R/intPID '
'Algo/R/desired '
'Algo/P/motErr '
'Algo/P/int1 '
'Algo/P/int2 '
'Algo/P/filtered '
'Algo/P/setptErr '
'Algo/P/intPID '
'Algo/P/desired '
'Algo/H/motErr '
'Algo/H/int1 '
'Algo/H/int2 '
'Algo/H/filtered '
'Algo/H/setptErr '
'Algo/H/intPID '
'Algo/H/desired '
'Algo/AP/APHead '
'Algo/AP/compHead '
'Algo/AP/compHeadFilt '
'Algo/A/speed '
'Algo/A/AvgSpeed '
'Algo/Fins/Raw/PC '
'Algo/Fins/Raw/SC '
'Algo/Fins/Raw/PS '
'Algo/Fins/Raw/SS '
'Algo/Fins/Gain/PC '
'Algo/Fins/Gain/SC '
'Algo/Fins/Gain/PS '
'Algo/Fins/Gain/SS '
'Algo/Fins/Offset/PC '
'Algo/Fins/Offset/SC '
'Algo/Fins/Offset/PS '
'Algo/Fins/Offset/SS '
'Algo/Fins/Delta/PC '
'Algo/Fins/Delta/SC '
'Algo/Fins/Delta/PS '
'Algo/Fins/Delta/SS '
'Algo/Fins/Cmd/PC '
'Algo/Fins/Cmd/SC '
'Algo/Fins/Cmd/PS '
'Algo/Fins/Cmd/SS '

```
'Algo/Fins/CmdNoOff/PC                    '
'Algo/Fins/CmdNoOff/SC                    '
'Algo/Fins/CmdNoOff/PS                    '
'Algo/Fins/CmdNoOff/SS                    '
'Algo/Flags/LowSpeeds                     '
'Algo/Flags/FastYawRate                   '
'Algo/Flags/FinOffsets                    '
];
units = [
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'psi '
'bar '
'psi '
'F   '
'F   '
'F   '
'bar '
'    '
'rpm '
'bar '
'bar '
'bar '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'    '
'psi '
'bar '
'psi '
'F   '
'F   '
'F   '
'bar '
'    '
'rpm '
'bar '
'bar '
'bar '
'    '
'    '
'    '
```

LMC-BALTIMORE RECORDED DATA

```
'     '
'     '
'     '
'     '
'     '
'     '
'C    '
'C    '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'C    '
'C    '
'rad  '
'rad  '
'rad  '
'rad  '
'     '
'psi  '
'psi  '
'gal  '
'ft   '
'psi  '
'gal  '
'ft   '
'psi  '
'gal  '
'ft   '
'     '
'psi  '
'psi  '
'gal  '
'ft   '
'psi  '
'gal  '
'ft   '
'psi  '
'gal  '
'ft   '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'rpm  '
```

LMC-BALTIMORE RECORDED DATA

```
'%    '
'rpm  '
'%    '
'     '
'     '
'kts  '
'     '
'kts  '
'kts  '
'fath'
'm    '
'ft   '
'C    '
'     '
'     '
'     '
'     '
'deg  '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'     '
'deg  '
'deg  '
'deg  '
'deg  '
'     '
'     '
'     '
'     '
'     '
'     '
'rad  '
'rad  '
'rad  '
'rad  '
'     '
'     '
'     '
'     '
```

LMC-BALTIMORE RECORDED DATA

MATLAB PLOT PROGRAM

```
load s8_6.mat;
data=data';

[nsamp nsigs] = size(data)



time=0.0:0.200000:0.200000*(nsamp -0.5);
timer=0.2:0.20000:0.200000*(nsamp -0.5);

%rawsbfin=57.3*(data(:,1)/4096-0.5);
%rawptfin=57.3*(data(:,2)/4096-0.5);
%rawsbstz=57.3*(data(:,3)/4096-0.5);
%rawptstz=57.3*(data(:,4)/4096-0.5);

pitch=57.3*data(:,119);
pitchr=57.3*data(:,120);
roll=57.3*data(:,121);
rollr=57.3*data(:,122);
yaw=data(:,123);
yawr=data(:,124);
yawrfilt=data(:,125);


crseprt=data(:,99);
crsestbd=data(:,100);


pitchjs=data(:,103);
rolljs=data(:,104);

speedknt=data(:,111);
depthft=data(:,117);

stbdstab=57.3*data(:,69);
portstab=57.3*data(:,70);
stbdfin=57.3*data(:,67);
portfin=57.3*data(:,68);

heading=data(:,149);

stbaftcs=57.3*data(:,157);
ptbaftcs=57.3*data(:,158);
stbfwdcs=57.3*data(:,155);
ptbfwdcs=57.3*data(:,156);

sstaberr= stbaftcs + stbdstab;
pstaberr= ptbaftcs + portstab;
sfinerr = stbfwdcs + stbdfin;
pfinerr = ptbfwdcs + portfin;

sfinoff=57.3*data(:,139);
pfinoff=57.3*data(:,140);
ssbzoff=57.3*data(:,141);
psbzoff=57.3*data(:,142);

portadju=57.3*data(:,93);
```

MATLAB PLOT PROGRAM

```
stbdadju=57.3*data(:,94);
apenable=data(:,95);
autoenab=data(:,98);

%CALCULATION OF CONTROL SURFACE RATES
stbdfwdr=diff(stbdfin)/0.2;
portfwdr=diff(portfin)/0.2;
stbdaftr=diff(stbdstab)/0.2;
portaftr=diff(portstab)/0.2;

%CALCULATION OF CONTROL SURFACE COMMAND RATES

sfcmdr=diff(stbfwdcs)/0.2;
pfcmdr=diff(ptbfwdcs)/0.2;
sscmdr=diff(stbaftcs)/0.2;
pscmdr=diff(ptbaftcs)/0.2;



mean(stbdstab)
mean(stbaftcs)
mean(ssbzoff)
mean(sstaberr)

%plot(time,apenable)


%plot(time,autoenab)

figure(1)
plot(time, speedknt,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('SHIP SPEED IN KNOTS')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_1.bmp


figure(2)
plot(time, pitch,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('PITCH ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_2.bmp


figure(3)
plot(time, roll,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('ROLL ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
```

```
pause
orient landscape
print -dbitmap s8_6_3.bmp


figure(4)
plot(time, yaw,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('YAW ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_4.bmp


figure(5)
plot(time,stbaftcs,'r',time,-stbdstab,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
text(22,-19.0,'RED - COMMAND  GREEN - ACTUAL POSITION`')
pause
orient landscape
print -dbitmap s8_6_5.bmp



figure(6)
plot(time, sstaberr,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD STABILIZER POSITIONING ERROR IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_6.bmp



figure(7)
plot(time,ptbaftcs,'r',time,-portstab,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('PORT STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
text(22,-19.0,'RED - COMMAND  GREEN - ACTUAL POSITION`')
pause
orient landscape
print -dbitmap s8_6_7.bmp


figure(8)
plot(time,pstaberr,'w')
grid
```

```
xlabel('TIME IN SECONDS')
ylabel('PORT STABILIZER POSITIONING ERROR IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_8.bmp



figure(9)
plot(timer,sscmdr,'r',timer,-stbdaftr,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC')
title('SLICE "SLICE" - RUN6')
text(22,-28.0,'RED - COMMAND RATE   GREEN - ACTUAL POSITION RATE')
pause
orient landscape
print -dbitmap s8_6_9.bmp



figure(10)
plot(timer,pscmdr,'r',timer,-portaftr,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('PORT STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC')
title('SLICE "SLICE" - RUN6')
text(22,-35.0,'RED - COMMAND RATE  GREEN - ACTUAL POSITION RATE')
pause
orient landscape
print -dbitmap s8_6_10.bmp


figure(11)
plot(time,stbfwdcs,'r',time,-stbdfin,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD FIN COMMAND AND FIN ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
text(22,-23.0,'RED - COMMAND  GREEN - ACTUAL POSITION')
pause
orient landscape
print -dbitmap s8_6_11.bmp


figure(12)
plot(time, sfinerr,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD FIN POSITIONING ERROR IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_12.bmp
```

MATLAB PLOT PROGRAM

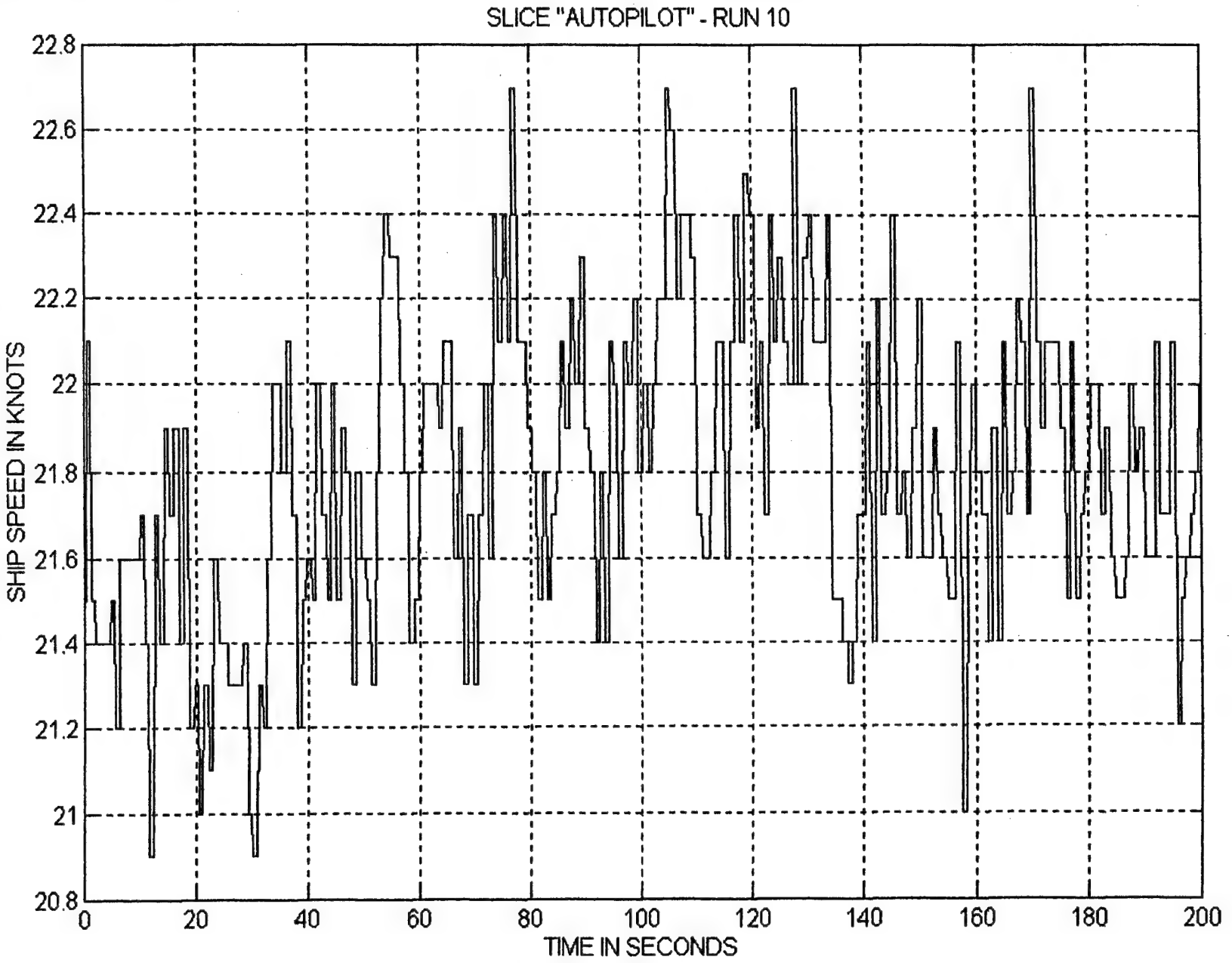
```
figure(13)
plot(time,ptbfwdcs,'r',time,-portfin,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('PORT FIN COMMAND AND FIN ANGLE IN DEGREEES')
title('SLICE "SLICE" - RUN6')
text(22,22.5,'RED - COMMAND  GREEN - ACTUAL POSITION')
pause
orient landscape
print -dbitmap s8_6_13.bmp


figure(14)
plot(time, pfinerr,'w')
grid
xlabel('TIME IN SECONDS')
ylabel('PORT FIN POSITIONING ERROR IN DEGREEES')
title('SLICE "SLICE" - RUN6')
pause
orient landscape
print -dbitmap s8_6_14.bmp



figure(15)
plot(timer,sfcmdr,'r',timer,-stbdfwdr,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('STARBOARD FIN COMMAND AND POSITION  RATES IN DEGREEES/SEC')
title('SLICE "SLICE" - RUN6')
text(22,-35.0,'RED - COMMAND RATE  GREEN - ACTUAL POSITION RATE')
pause
orient landscape
print -dbitmap s8_6_15.bmp


figure(16)
plot(timer,pfcmdr,'r',timer,-portfwdr,'g')
grid
xlabel('TIME IN SECONDS')
ylabel('PORT FIN COMMAND AND POSITION RATES IN DEGREEES/SEC')
title('SLICE "SLICE" - RUN6')
text(22,-35.0,'RED - COMMAND RATE  GREEN - ACTUAL POSITION RATE')
pause
orient landscape
print -dbitmap s8_6_16.bmp


%plot(time,rawsbfin,'r',time,rawptfin,'g')
%grid
%xlabel('TIME IN SECONDS')
%ylabel(' RAW STARBOARD AND PORT FIN COMMANDS')
%title('SLICE "SLICE" - RUN6')
%text(22,-7.5,'RED - STARBOARD  GREEN - PORT')
```

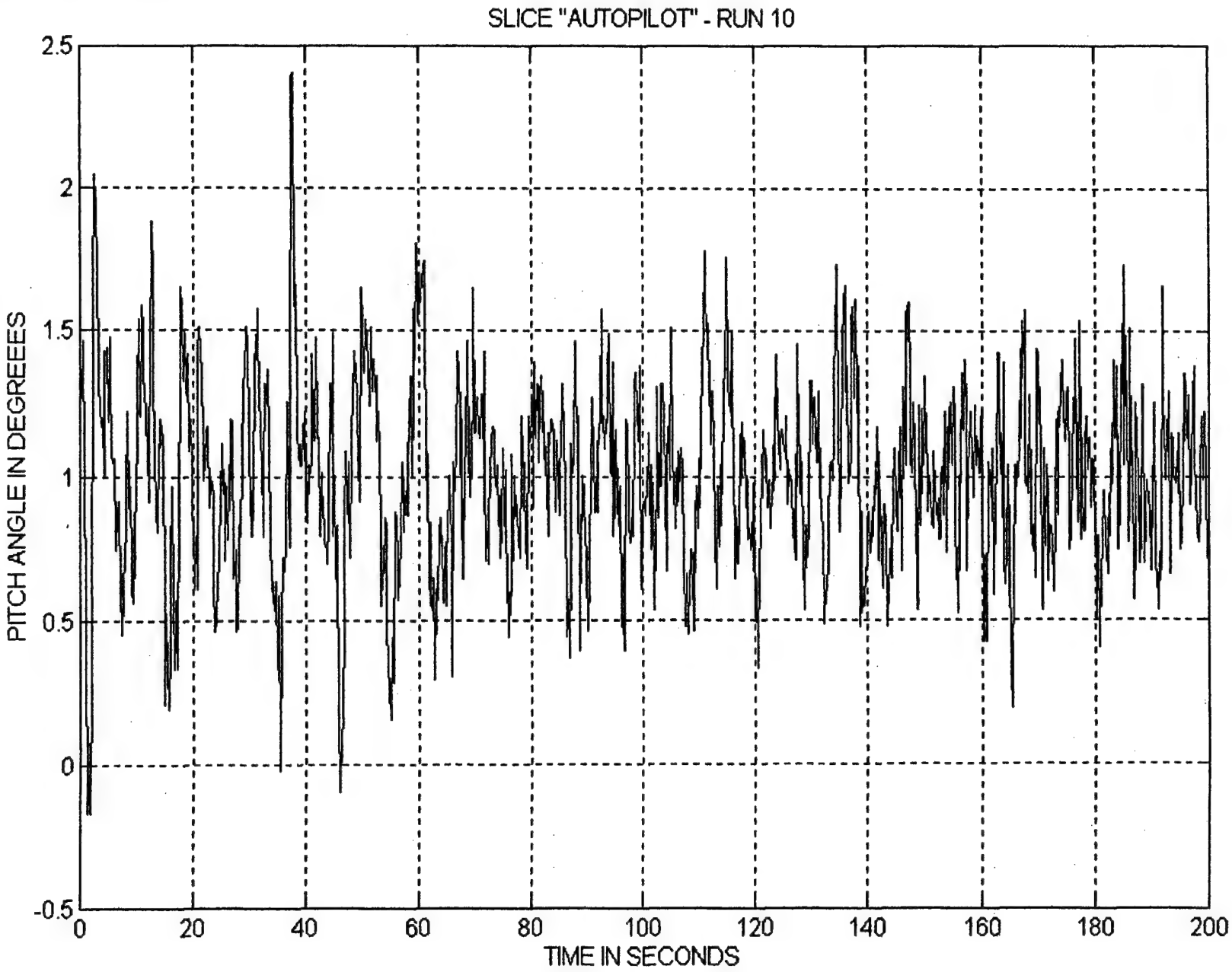
MATLAB PLOT PROGRAM

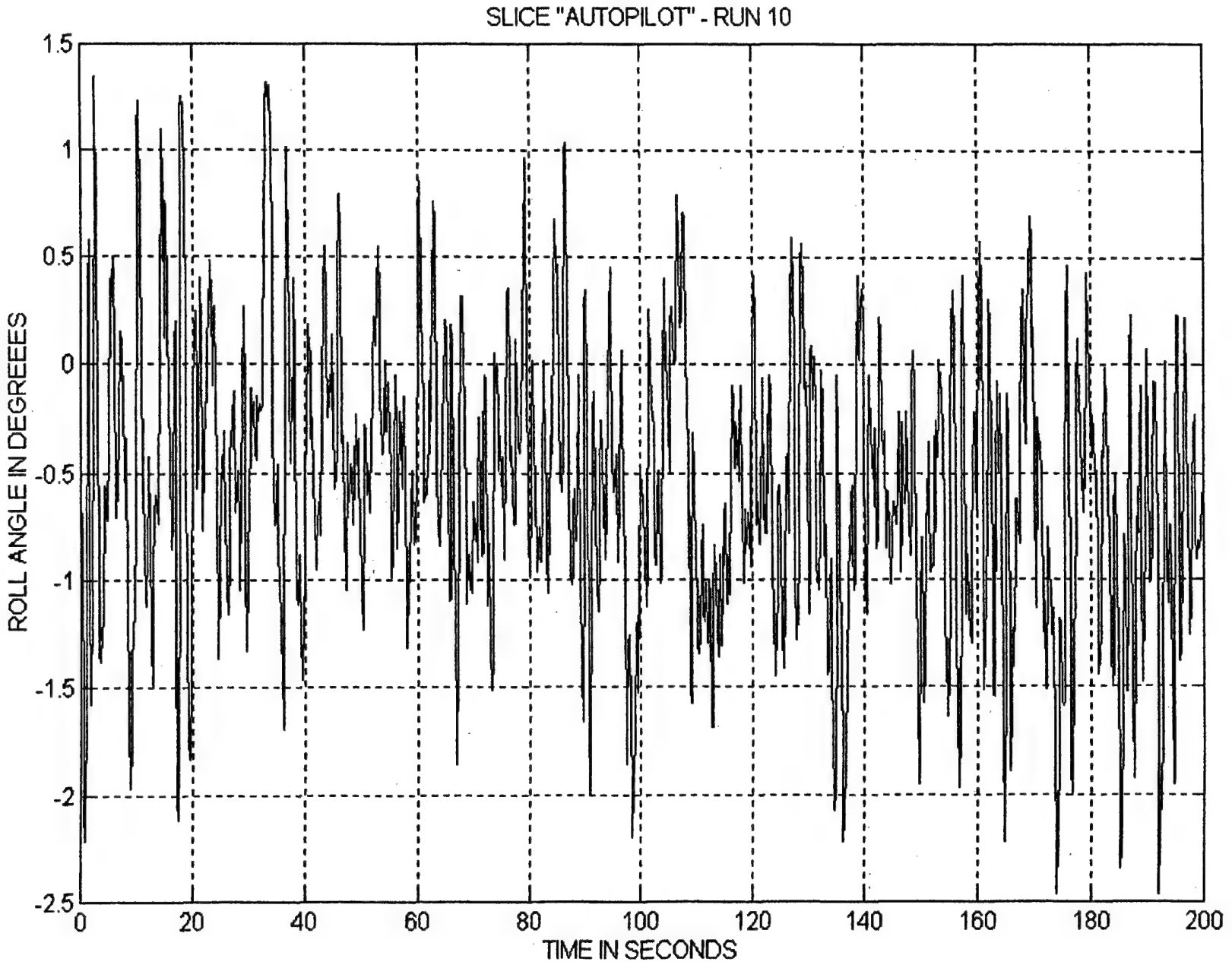
```
%orient landscape
%print -dbitmap s8_6_1.bmp

%
%plot(time,rawsbstz,'r',time,rawptstz,'g')
%grid
%xlabel('TIME IN SECONDS')
%ylabel('RAW STARBOARD AND PORT STABILIZER COMMANDS')
%title('SLICE "SLICE" - RUN6')
%text(22,-7.5,'RED - STARBOARD  GREEN - PORT`')

%orient landscape
%print -dbitmap s8_6_1.bmp

%
```

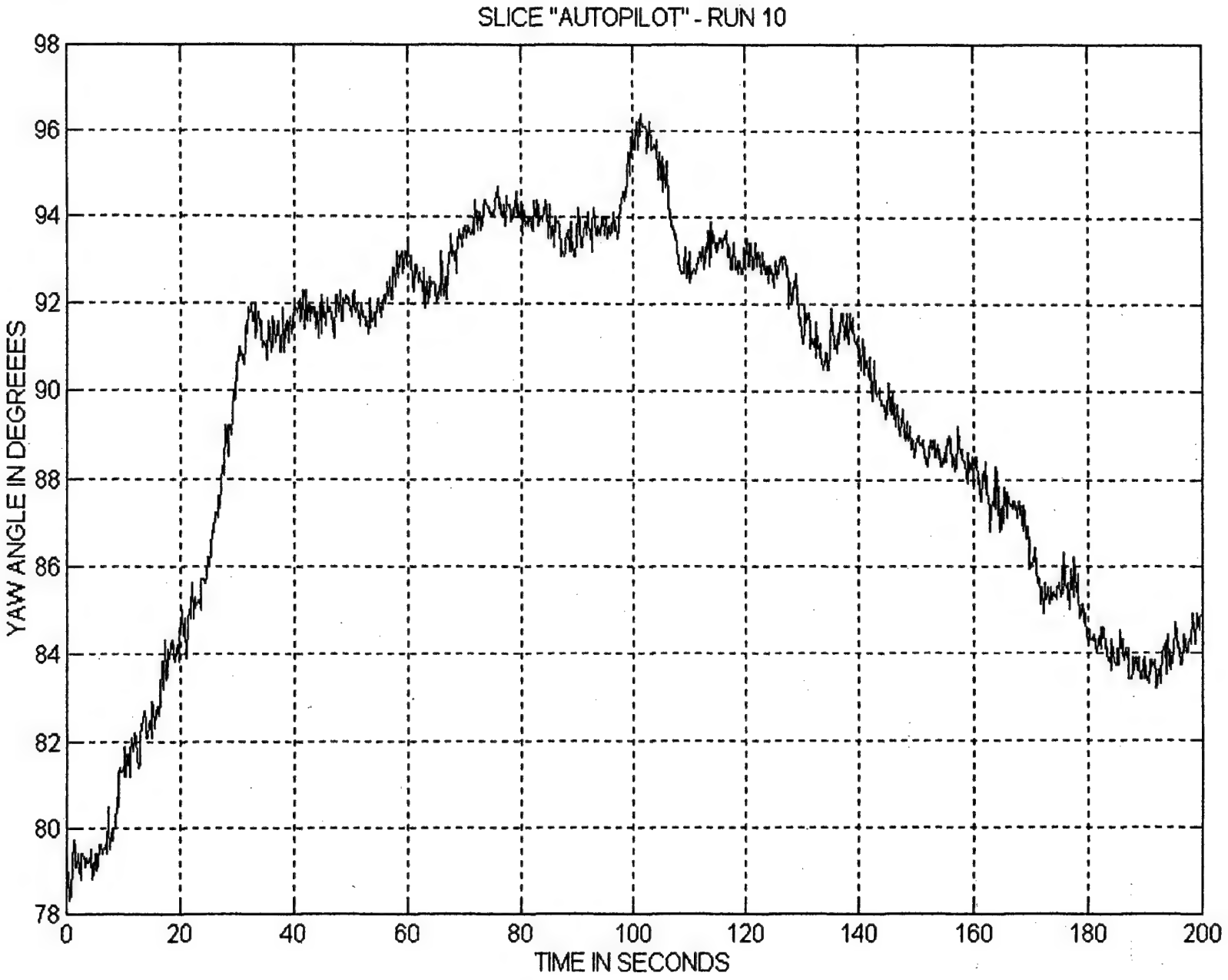
APPENDIX C

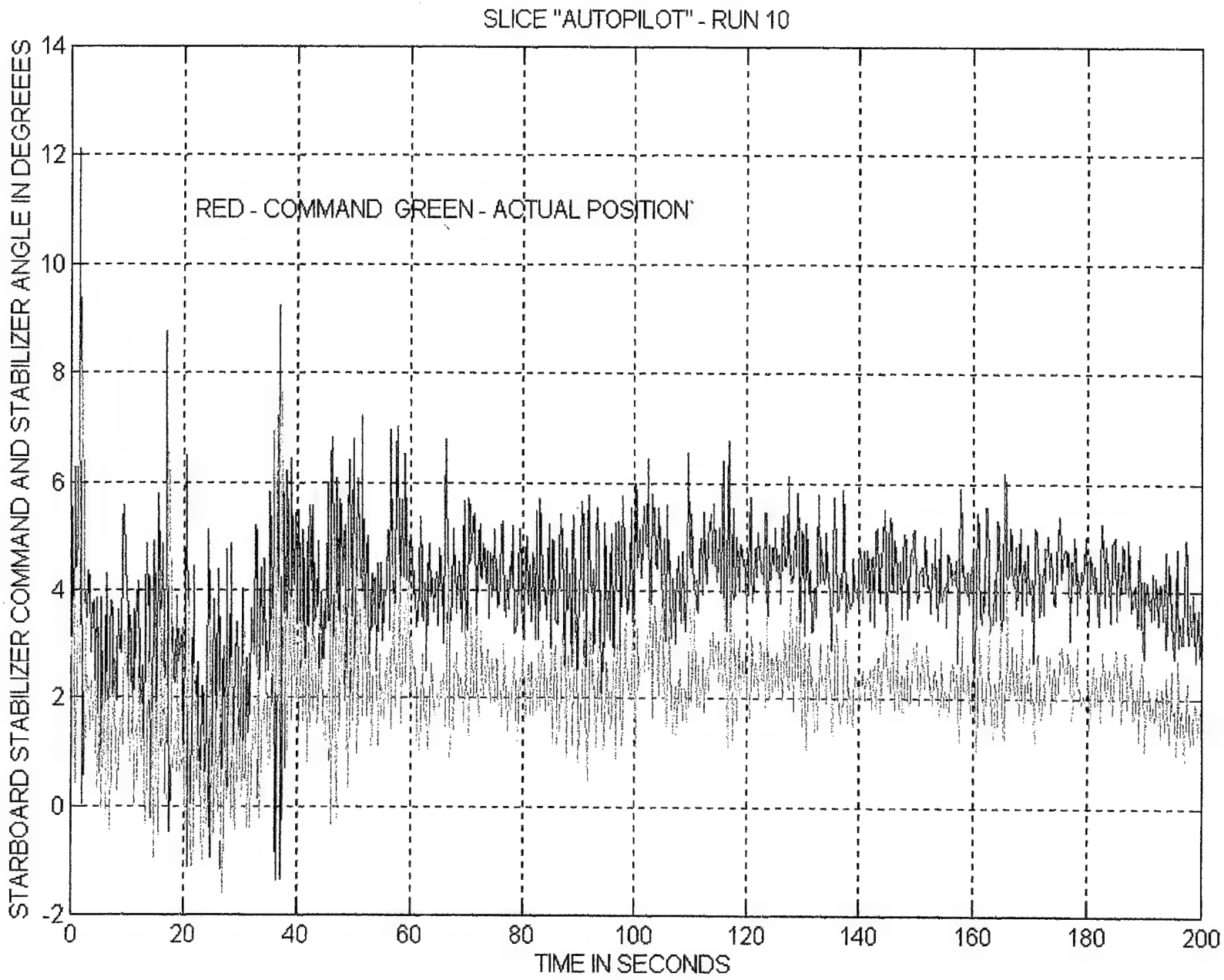
SLICE AUTOPILOT RUN ID Autoplilot_08_Nov00_12_51_01

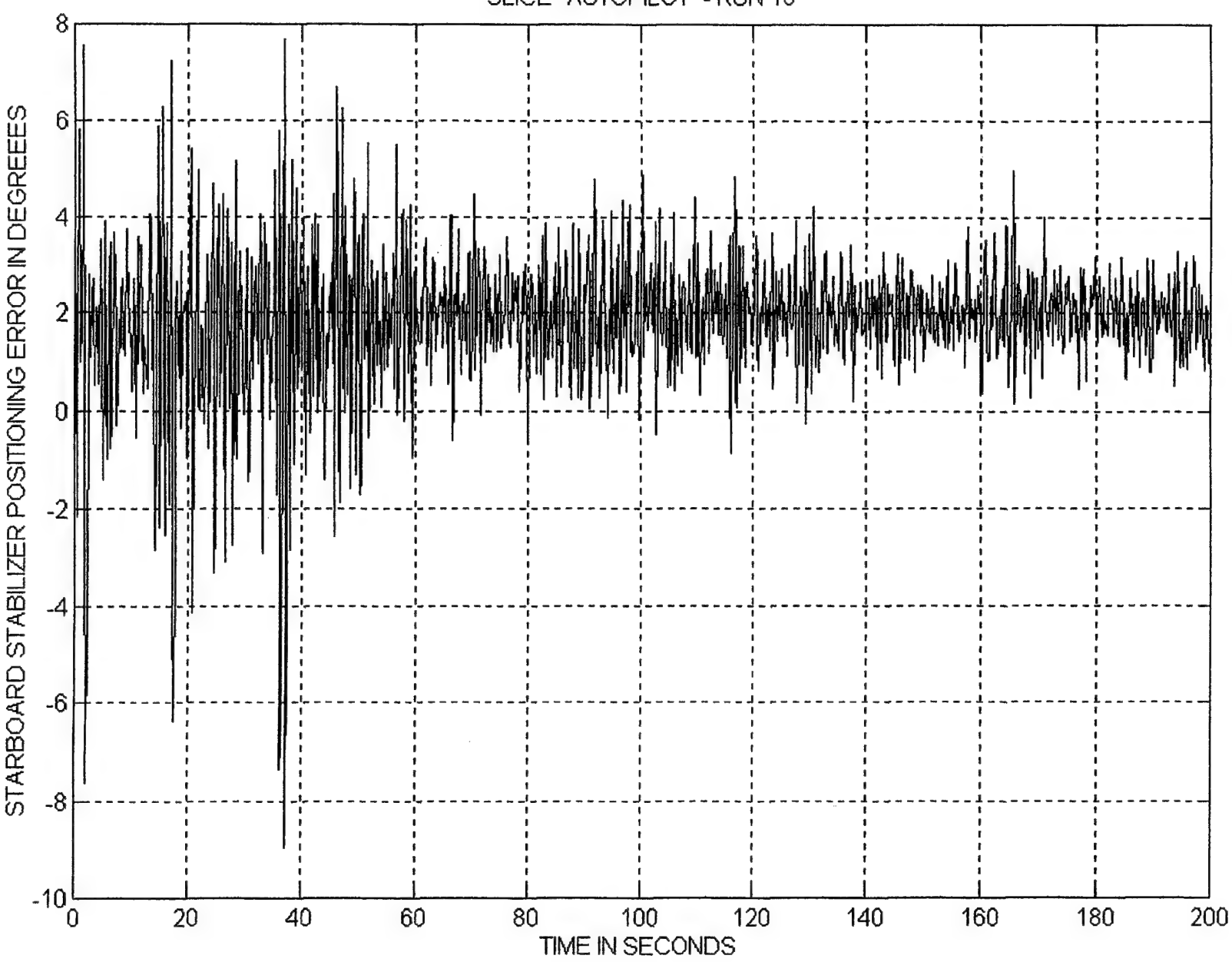

SLICE "AUTOPILOT" - RUN 10
SHIP SPEED IN KNOTS
TIME IN SECONDS
22.8
22.6
22.4
22.2
22
21.8
21.6
21.4
21.2
21
20.8
0
20
40
60
80
100
120
140
160
180
200

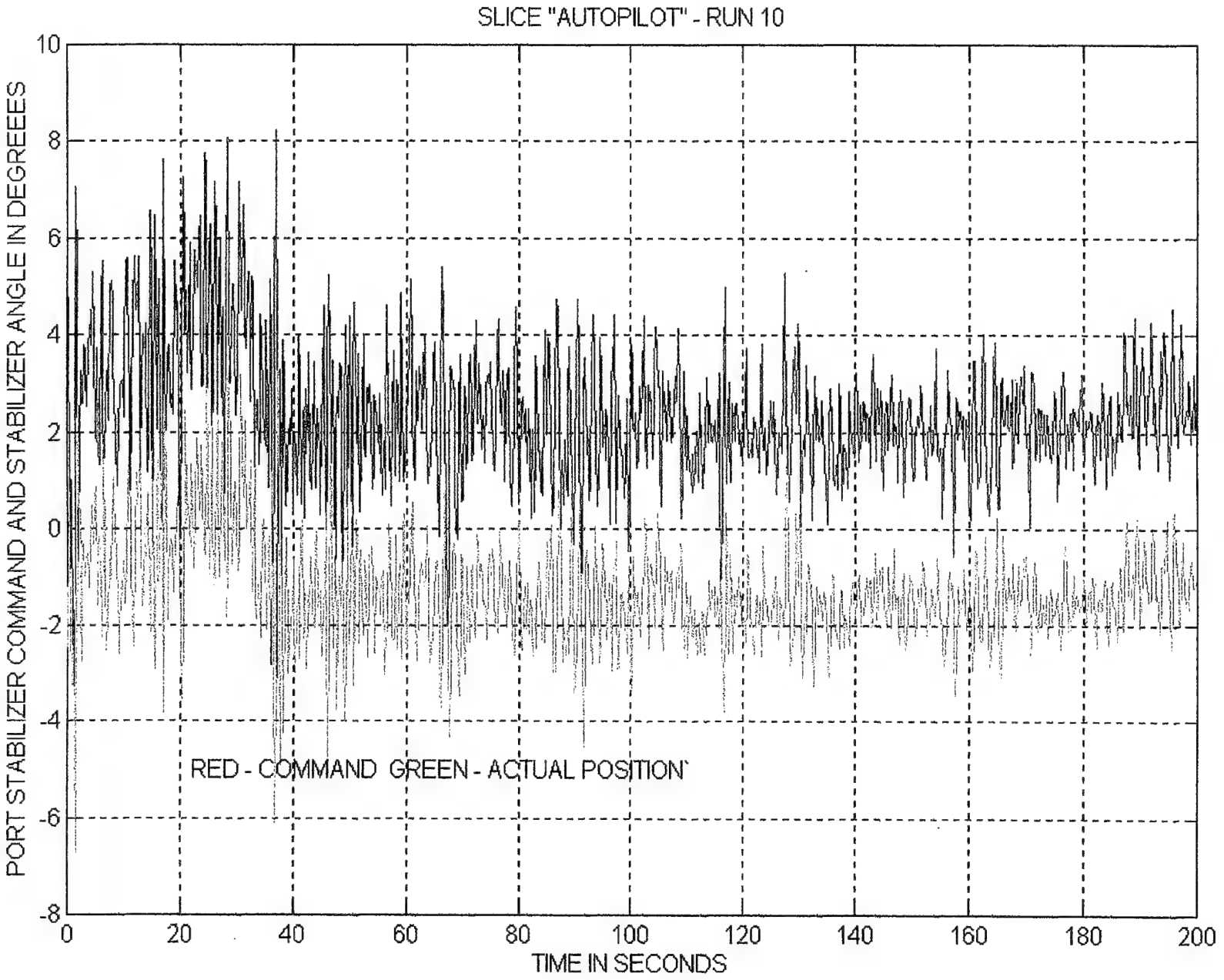

SLICE "AUTOPILOT" - RUN 10
PITCH ANGLE IN DEGREEES
TIME IN SECONDS
2.5
2
1.5
1
0.5
0
-0.5
0
20
40
60
80
100
120
140
160
180
200

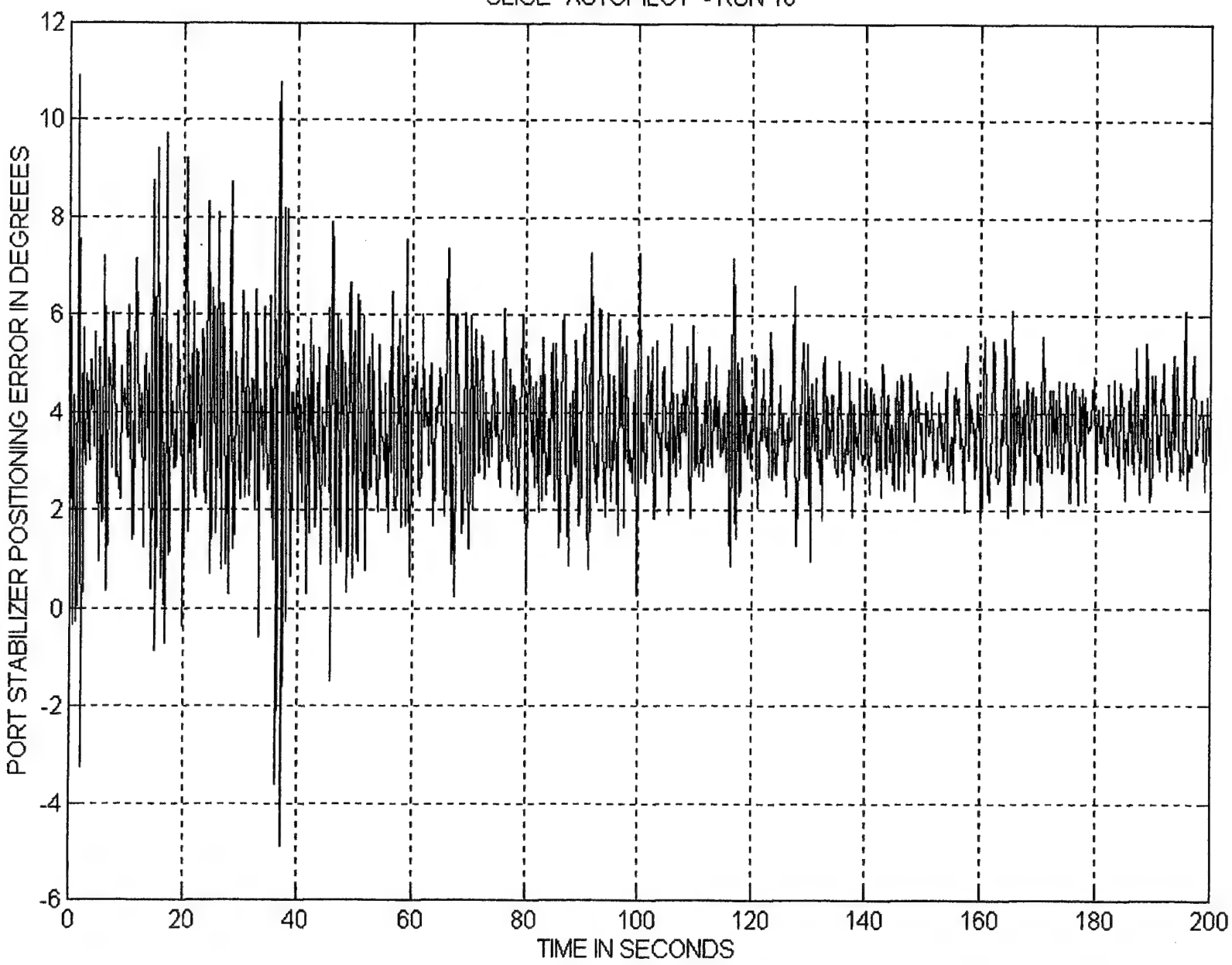

SLICE "AUTOPILOT" - RUN 10
ROLL ANGLE IN DEGREEES
TIME IN SECONDS
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
20
40
60
80
100
120
140
160
180
200

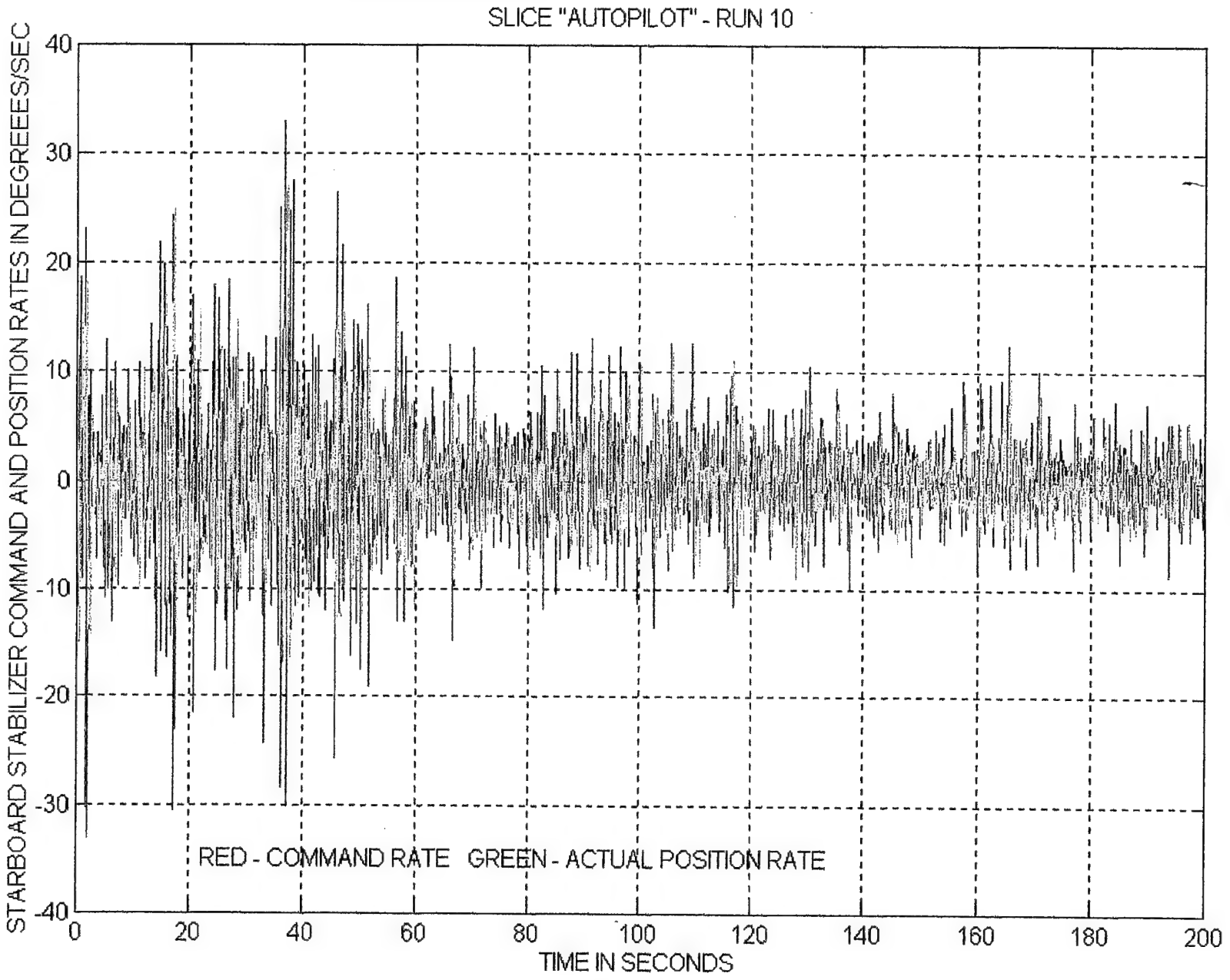

SLICE "AUTOPILOT" - RUN 10
YAW ANGLE IN DEGREEES
TIME IN SECONDS
98
96
94
92
90
88
86
84
82
80
78
0
20
40
60
80
100
120
140
160
180
200

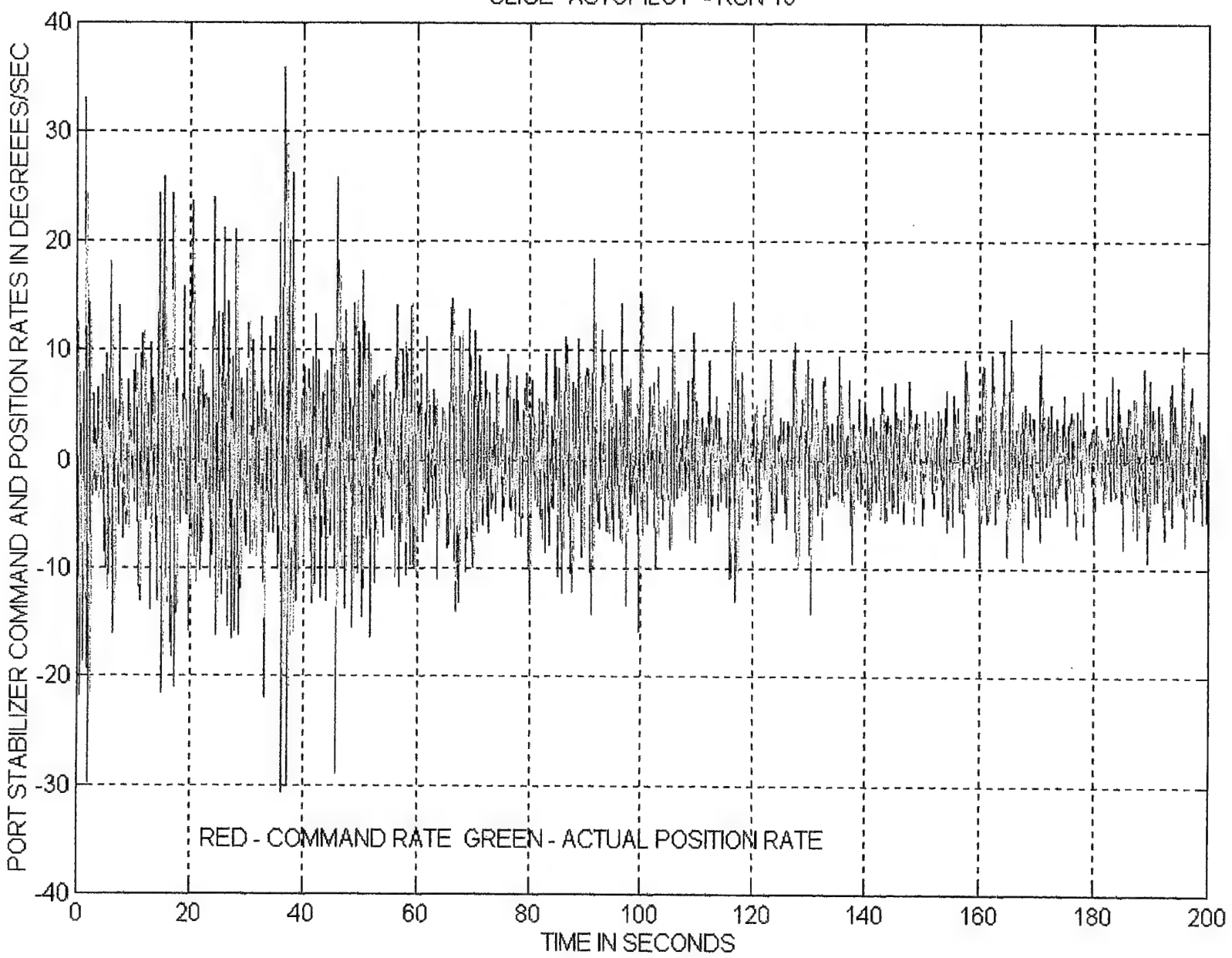

SLICE "AUTOPILOT" - RUN 10
RED - COMMAND GREEN - ACTUAL POSITION
STARBOARD STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES
TIME IN SECONDS
14
12
10
8
6
4
2
0
-2
0
20
40
60
80
100
120
140
160
180
200

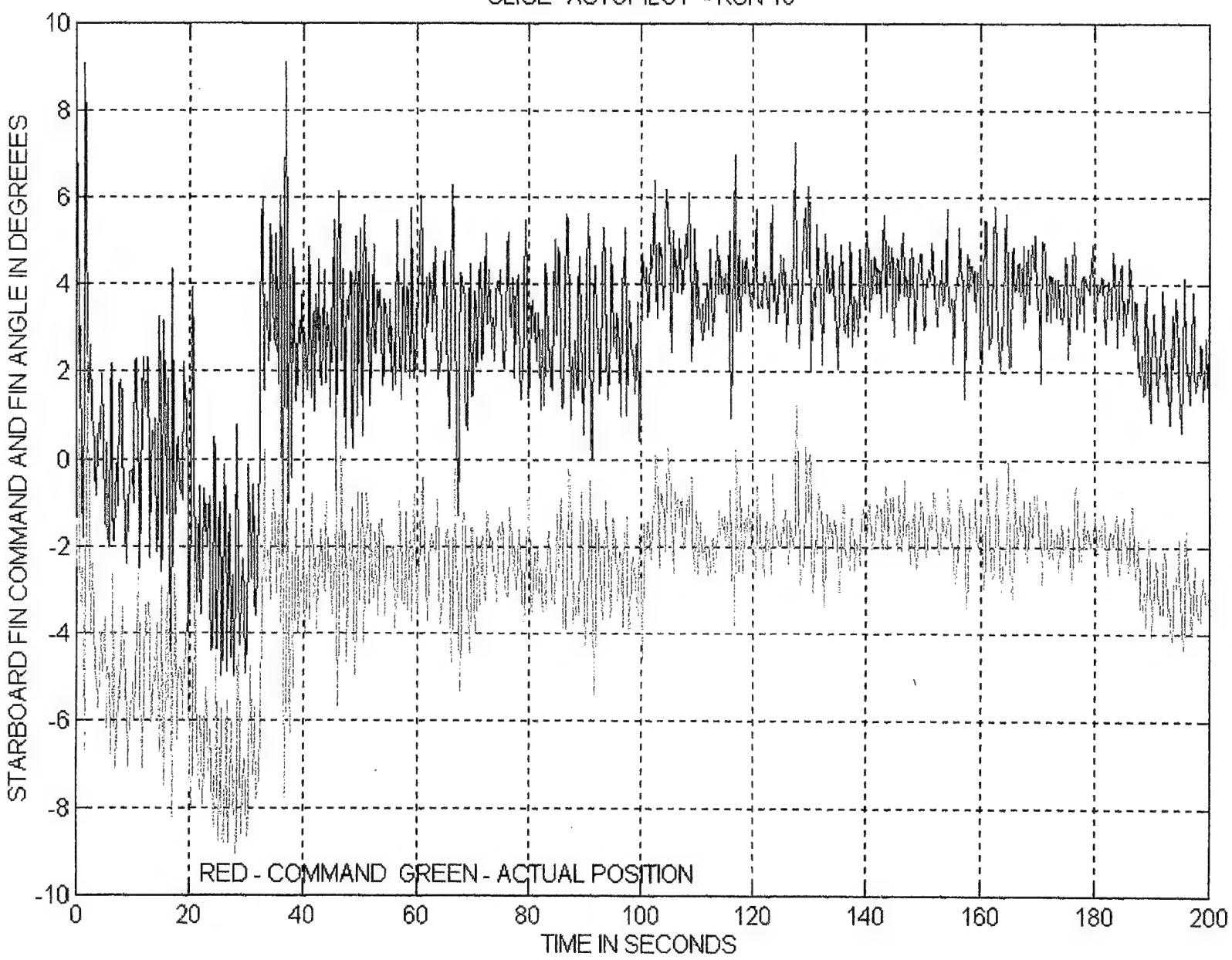

SLICE "AUTOPILOT" - RUN 10
STARBOARD STABILIZER POSITIONING ERROR IN DEGREEES
8
6
4
2
0
-2
-4
-6
-8
-10
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS

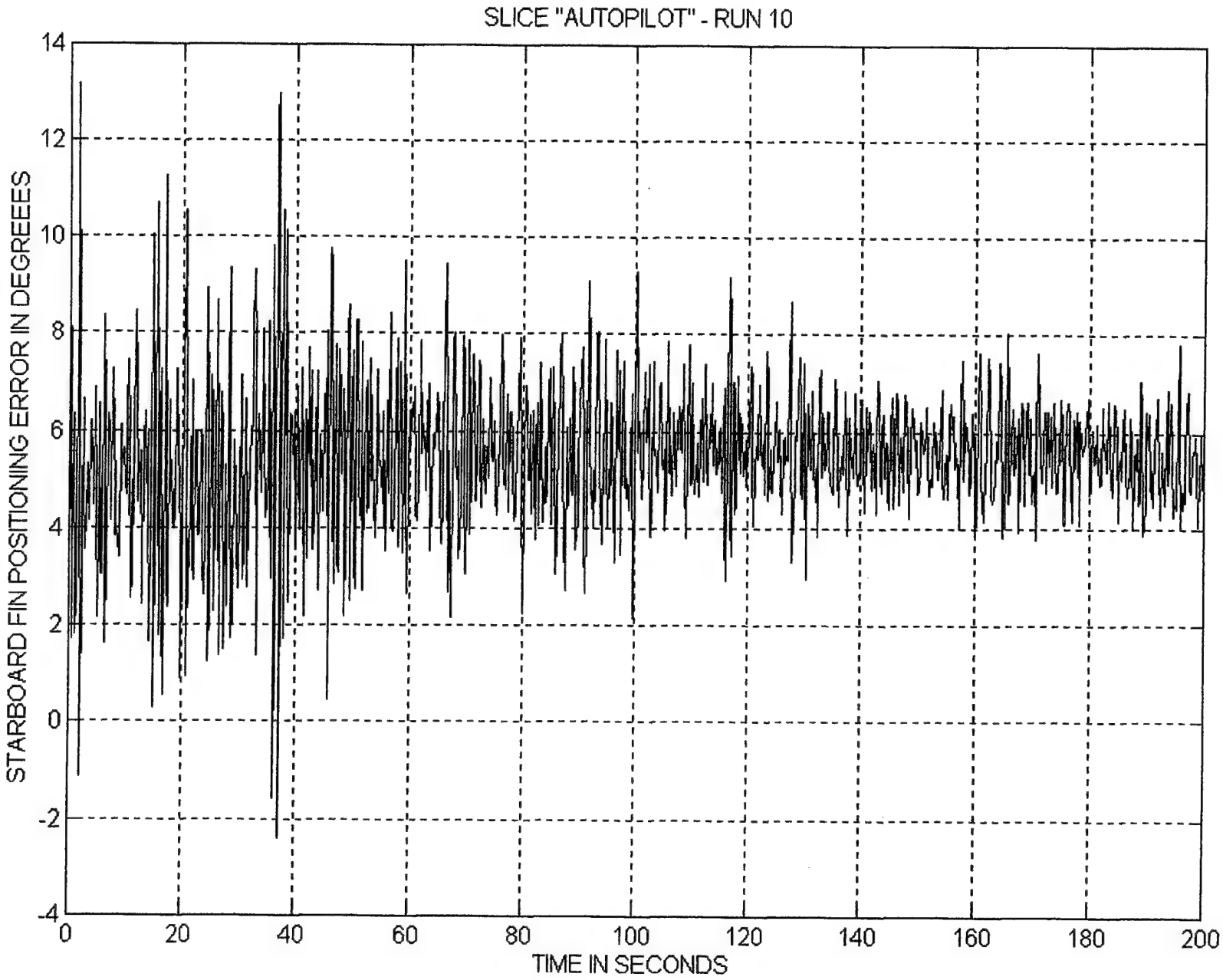

SLICE "AUTOPILOT" - RUN 10
PORT STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION
10
8
6
4
2
0
-2
-4
-6
-8
0
20
40
60
80
100
120
140
160
180
200

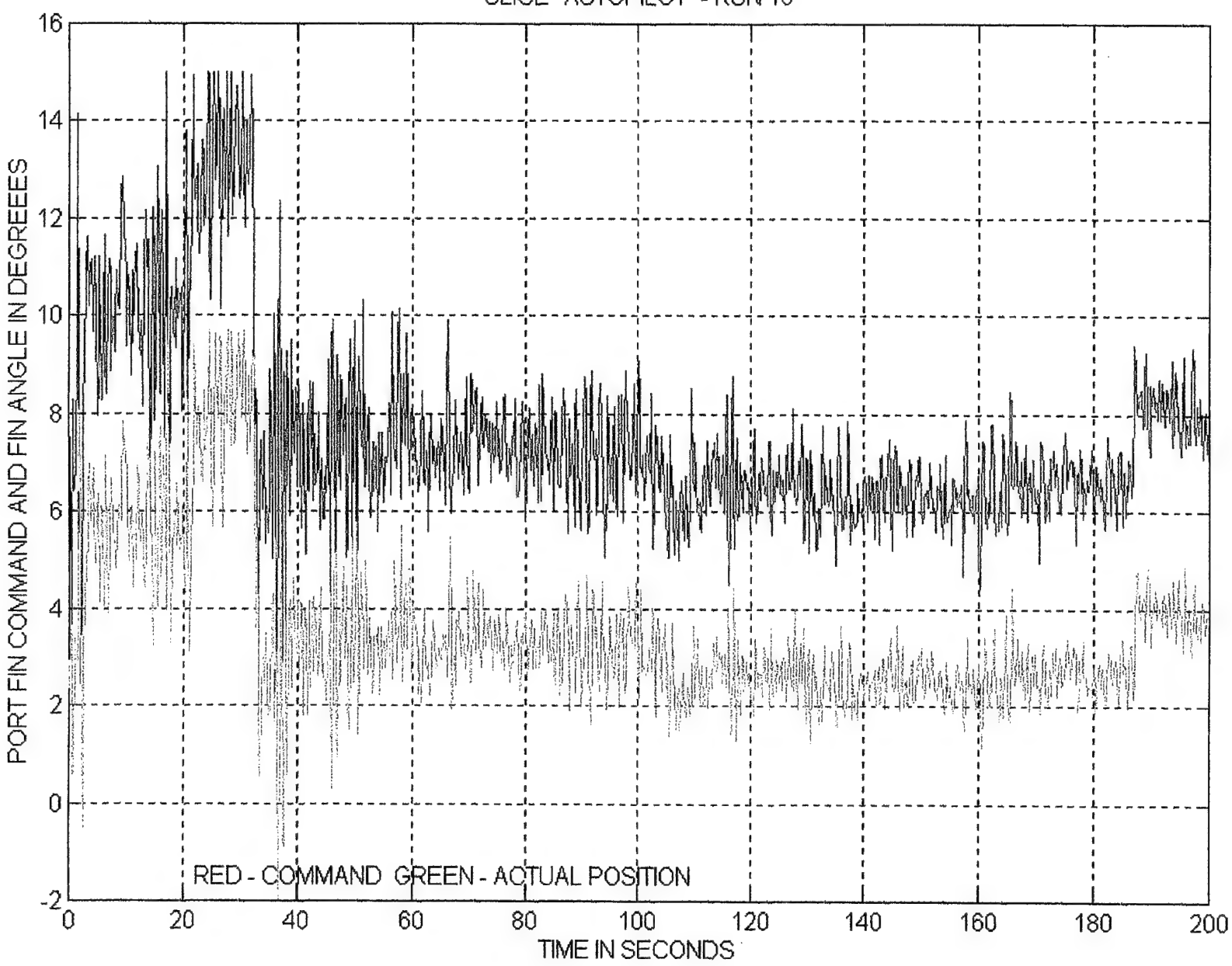

SLICE "AUTOPILOT" - RUN 10
PORT STABILIZER POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
180
200

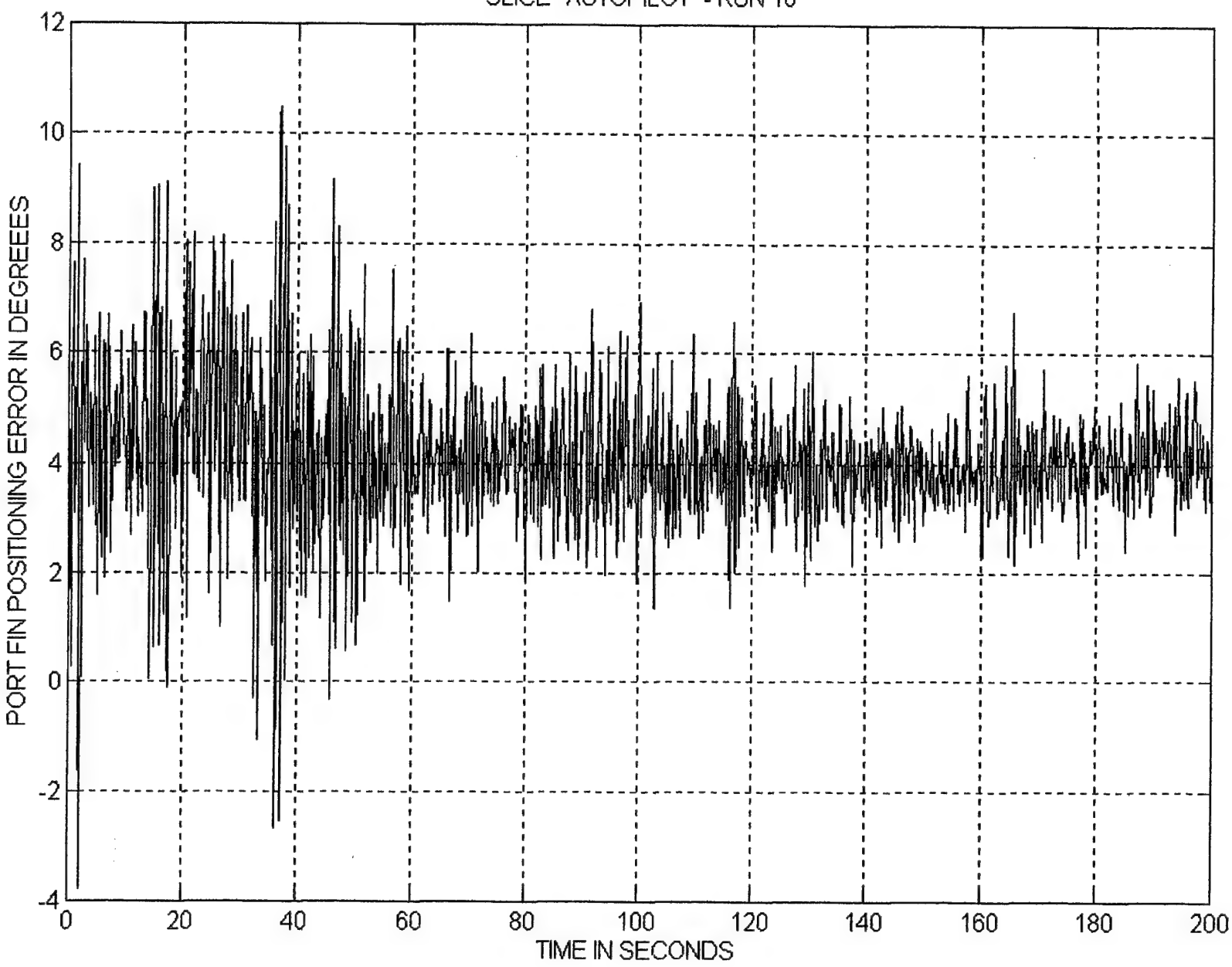

SLICE "AUTOPILOT" - RUN 10
STARBOARD STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE

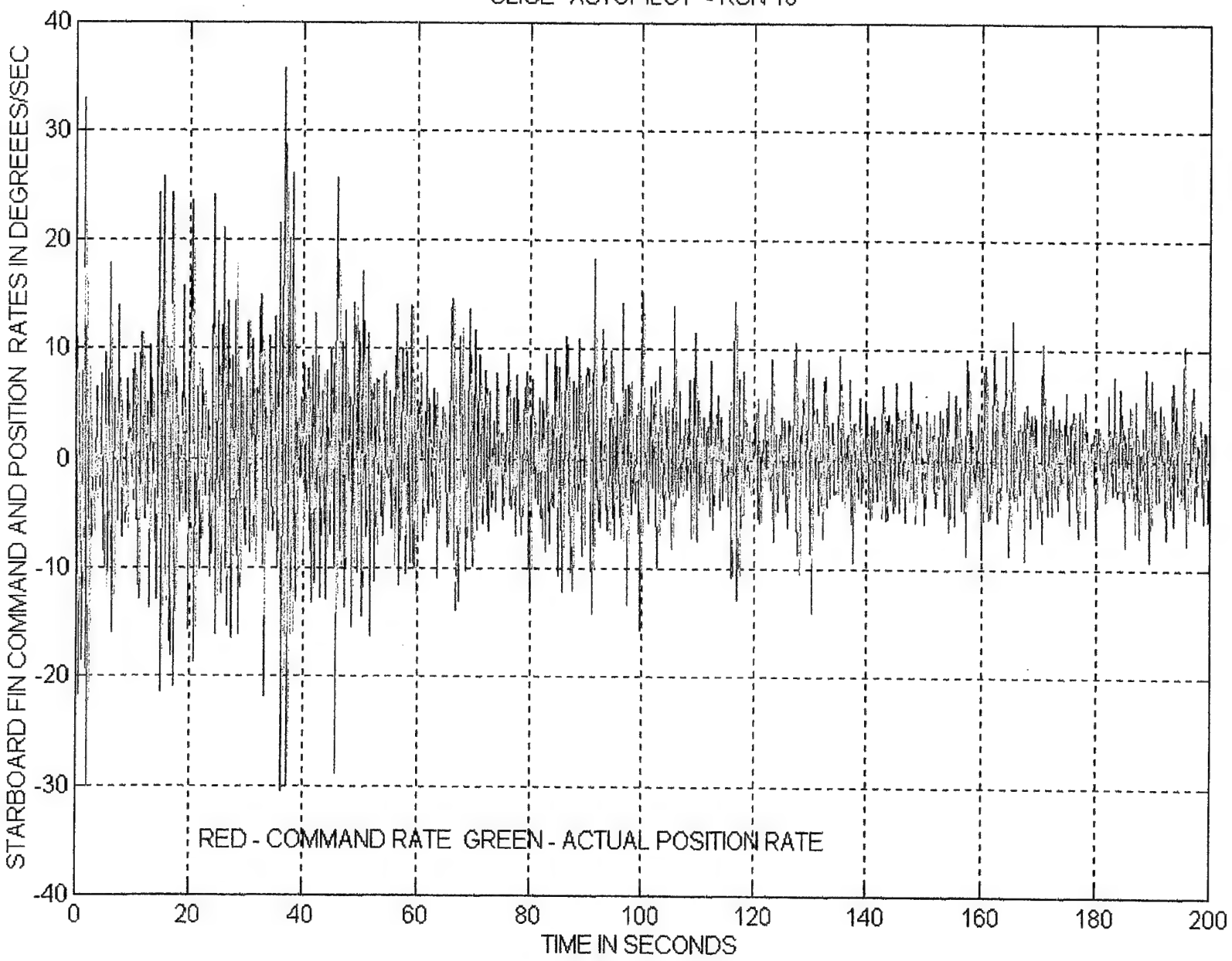

SLICE "AUTOPILOT" - RUN 10
PORT STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE


SLICE "AUTOPILOT" - RUN 10
STARBOARD FIN COMMAND AND FIN ANGLE IN DEGREEES
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION


SLICE "AUTOPILOT" - RUN 10
STARBOARD FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
14
12
10
8
6
4
2
0
-2
-4
0
20
40
60
80
100
120
140
160
180
200


SLICE "AUTOPILOT" - RUN 10
PORT FIN COMMAND AND FIN ANGLE IN DEGREEES
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION
16
14
12
10
8
6
4
2
0
-2
0
20
40
60
80
100
120
140
160
180
200

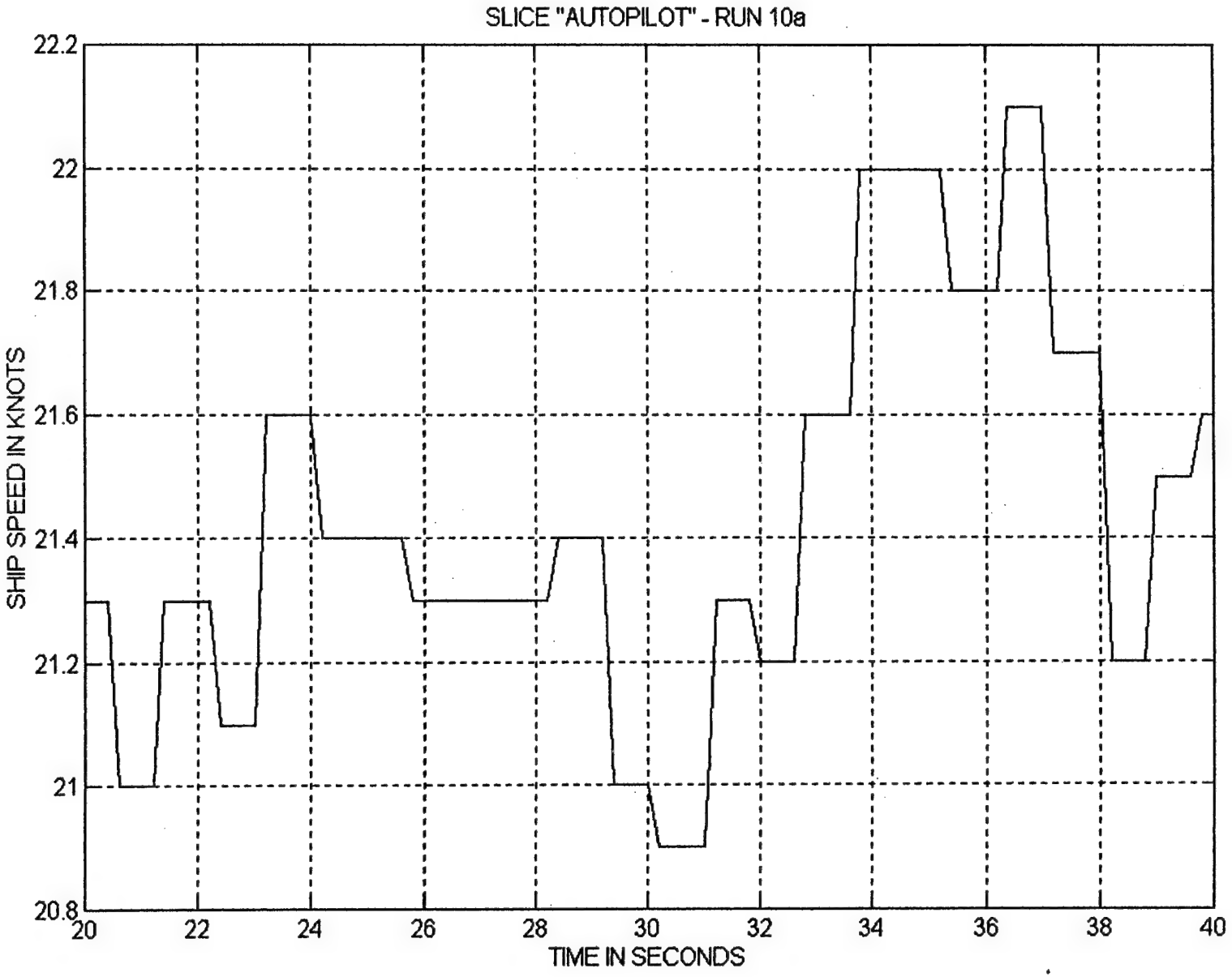

SLICE "AUTOPILOT" - RUN 10
PORT FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
0
20
40
60
80
100
120
140
160
180
200

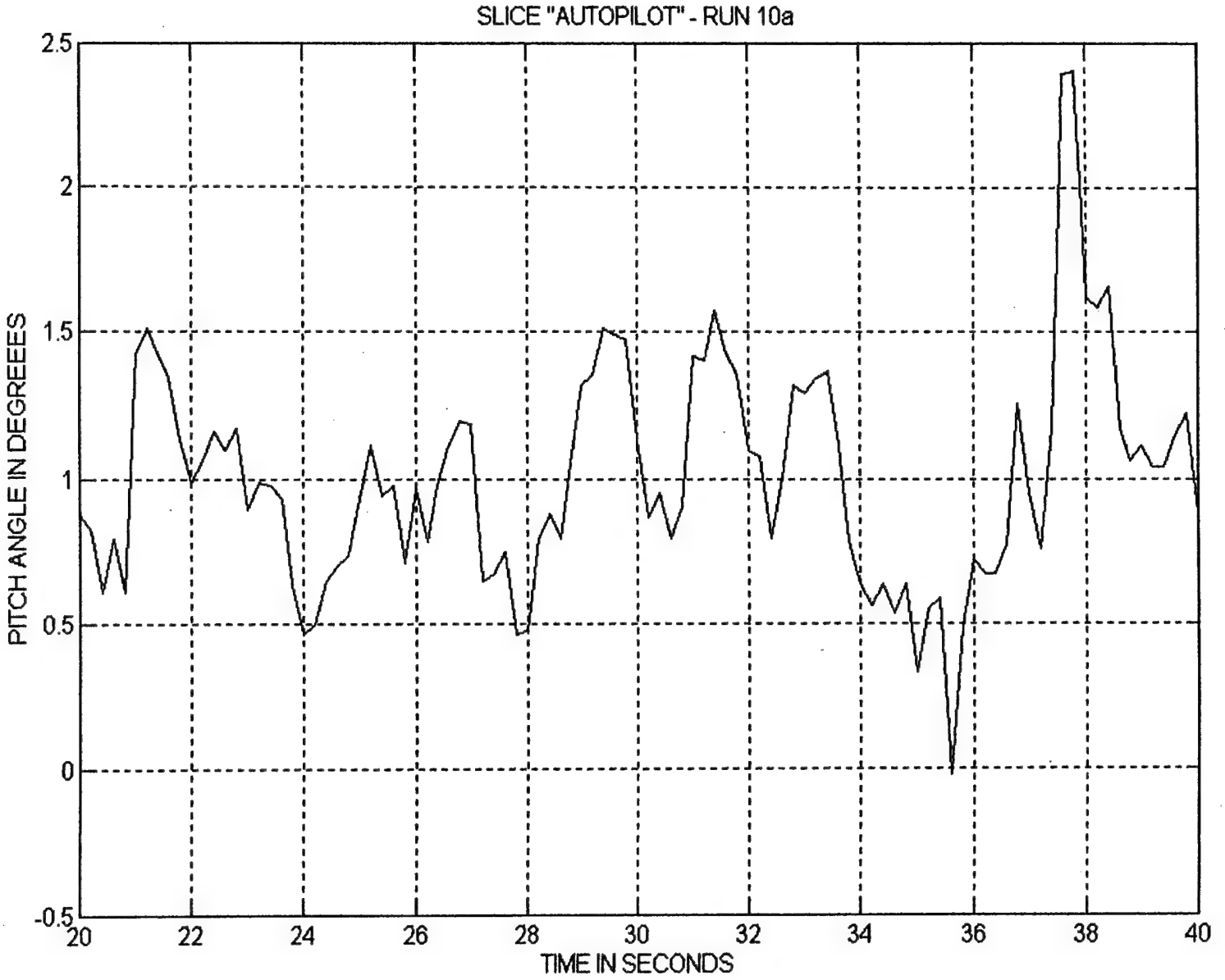

SLICE "AUTOPILOT" - RUN 10
STARBOARD FIN COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE

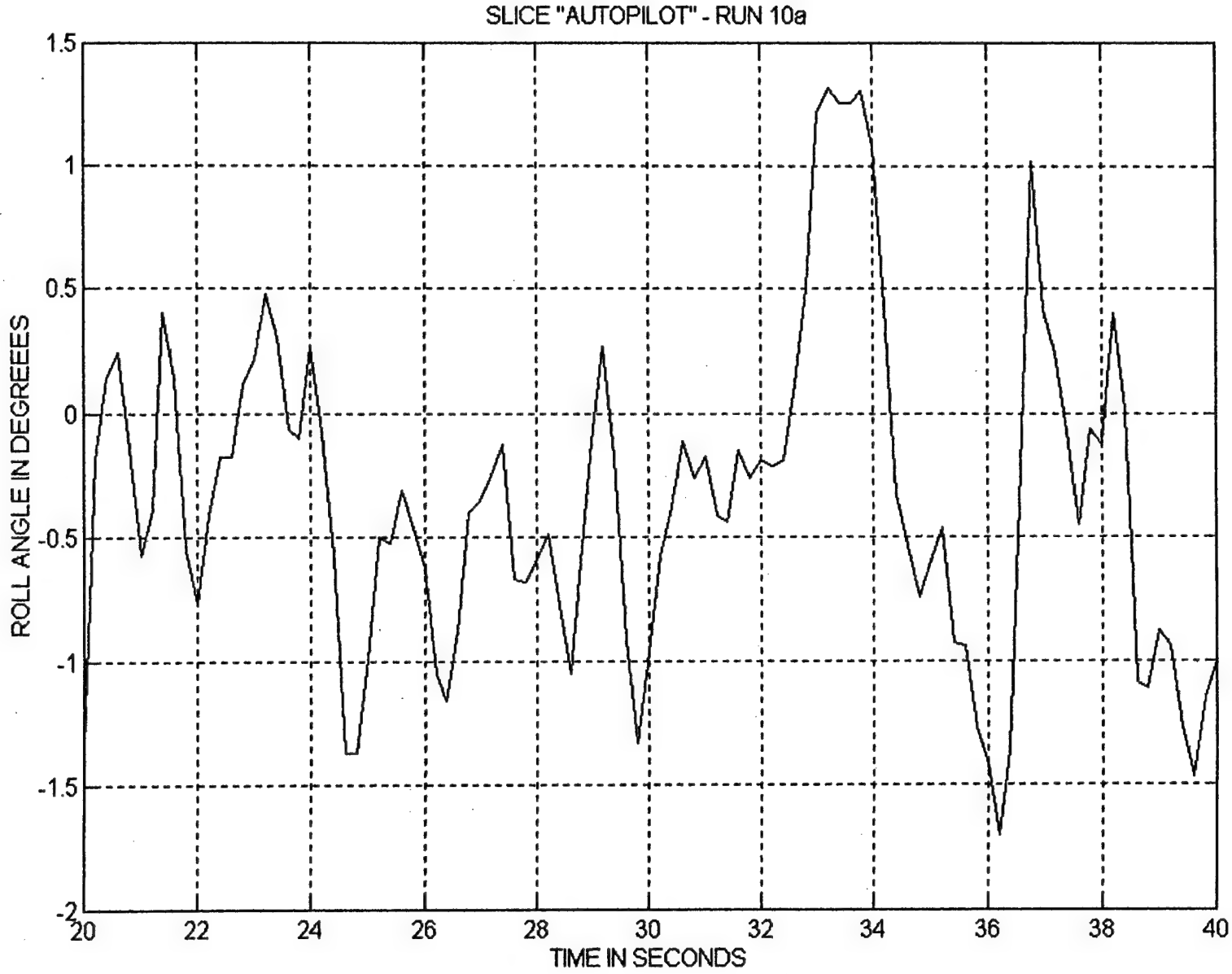
APPENDIX D

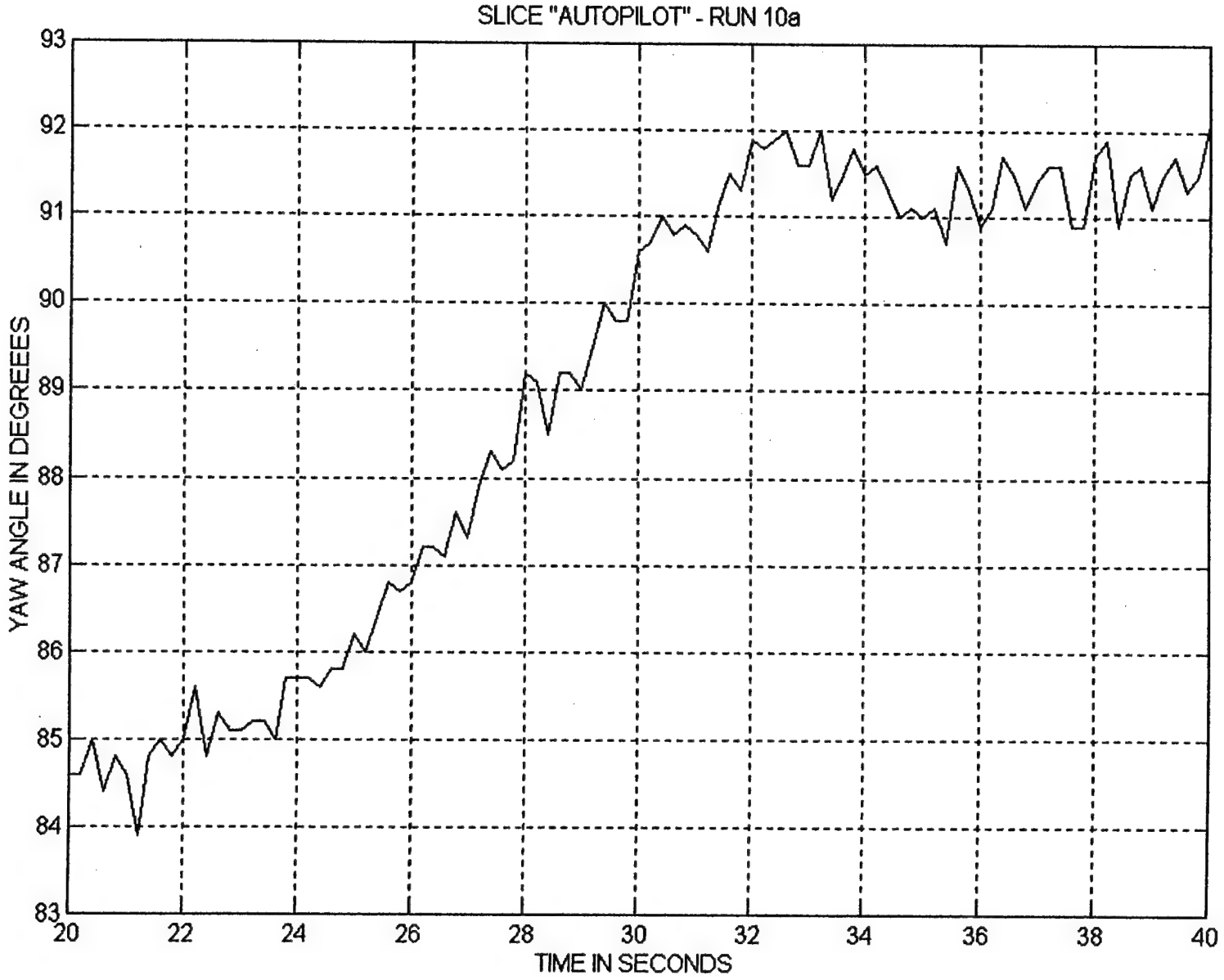
SLICE AUTOPILOT RUN ID Autoplilot_08_Nov00_12_51_01

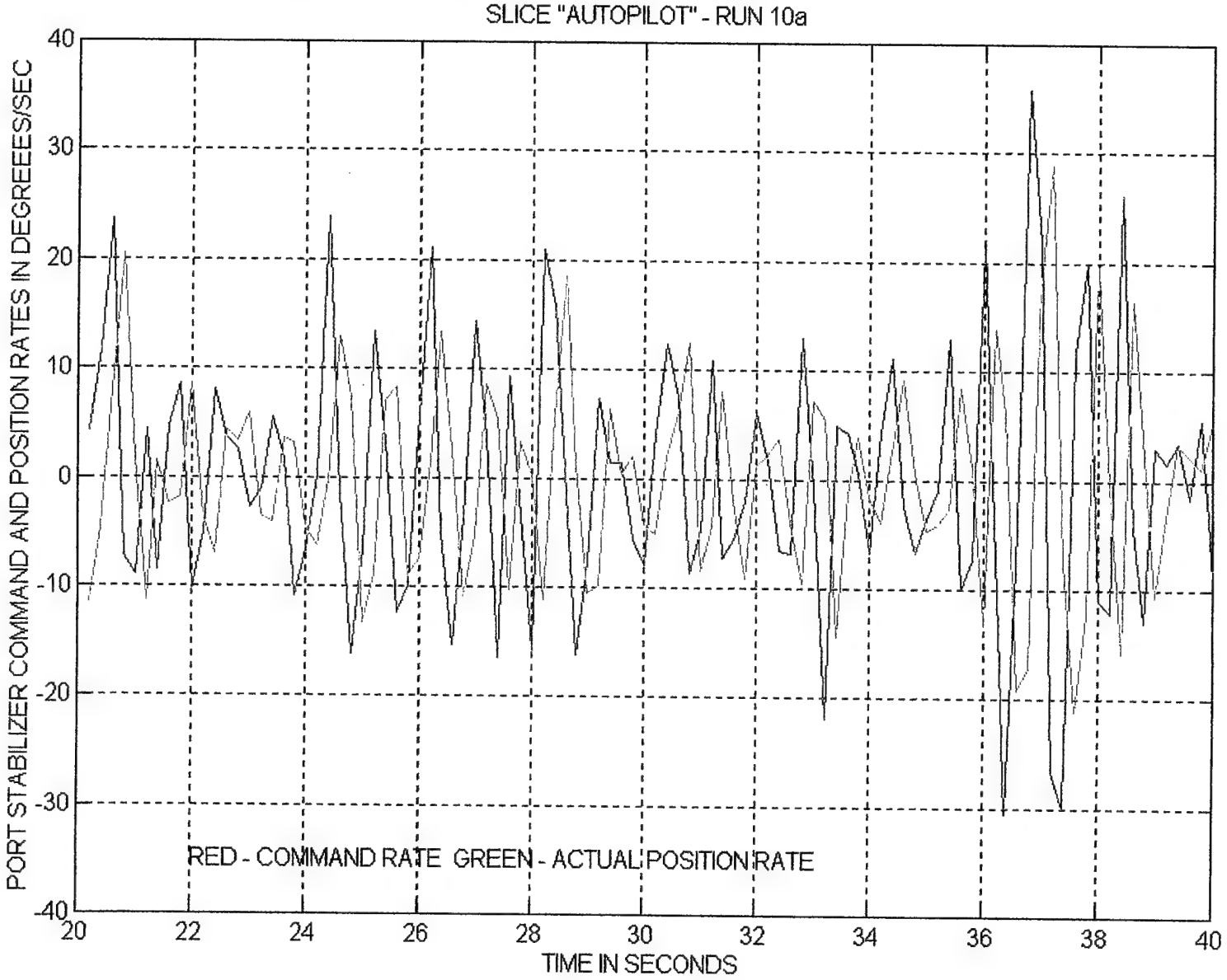
20 SECOND TIME CLIP

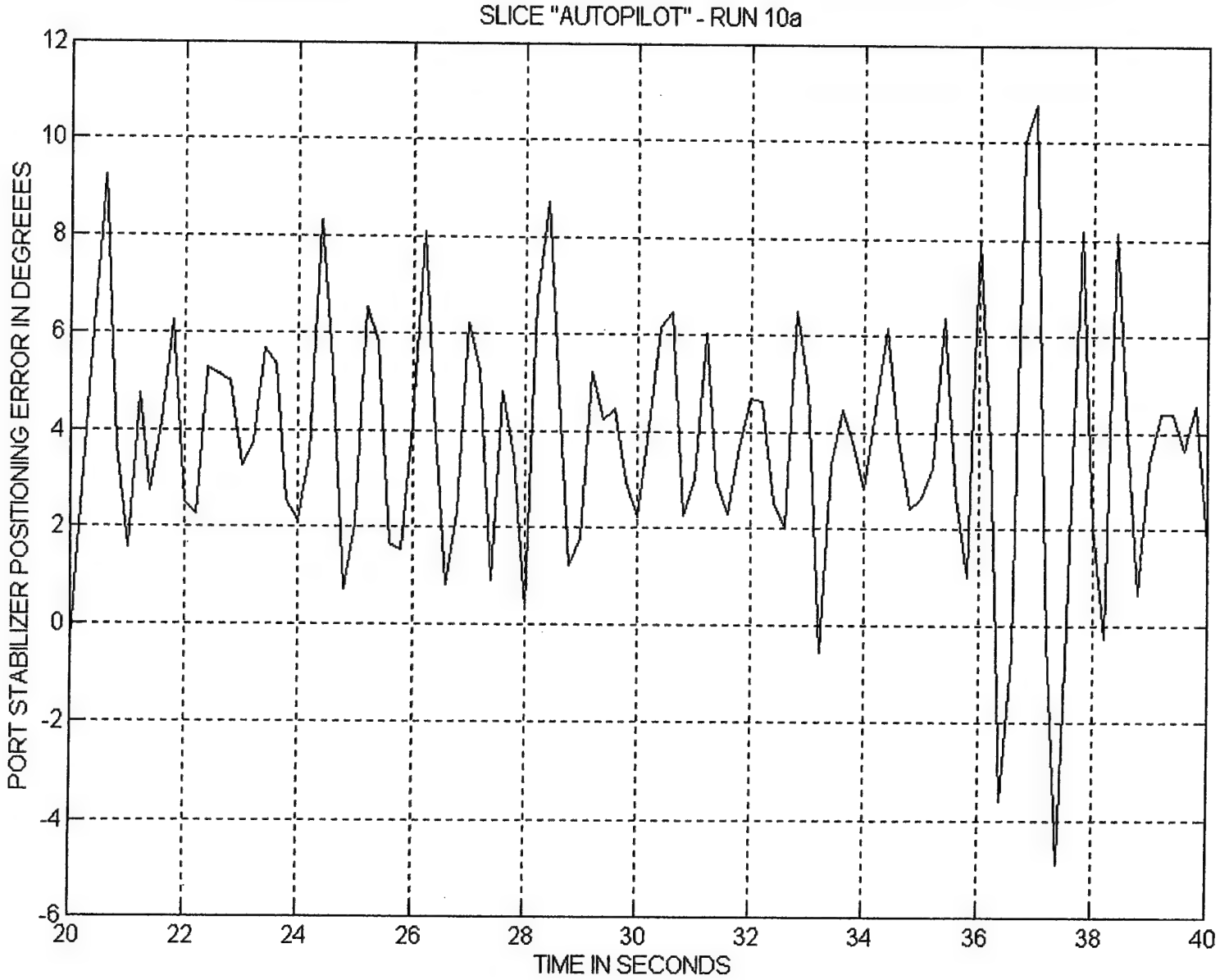

SLICE "AUTOPILOT" - RUN 10a
SHIP SPEED IN KNOTS
22.2
22
21.8
21.6
21.4
21.2
21
20.8
20
22
24
26
28
30
32
34
36
38
40
TIME IN SECONDS

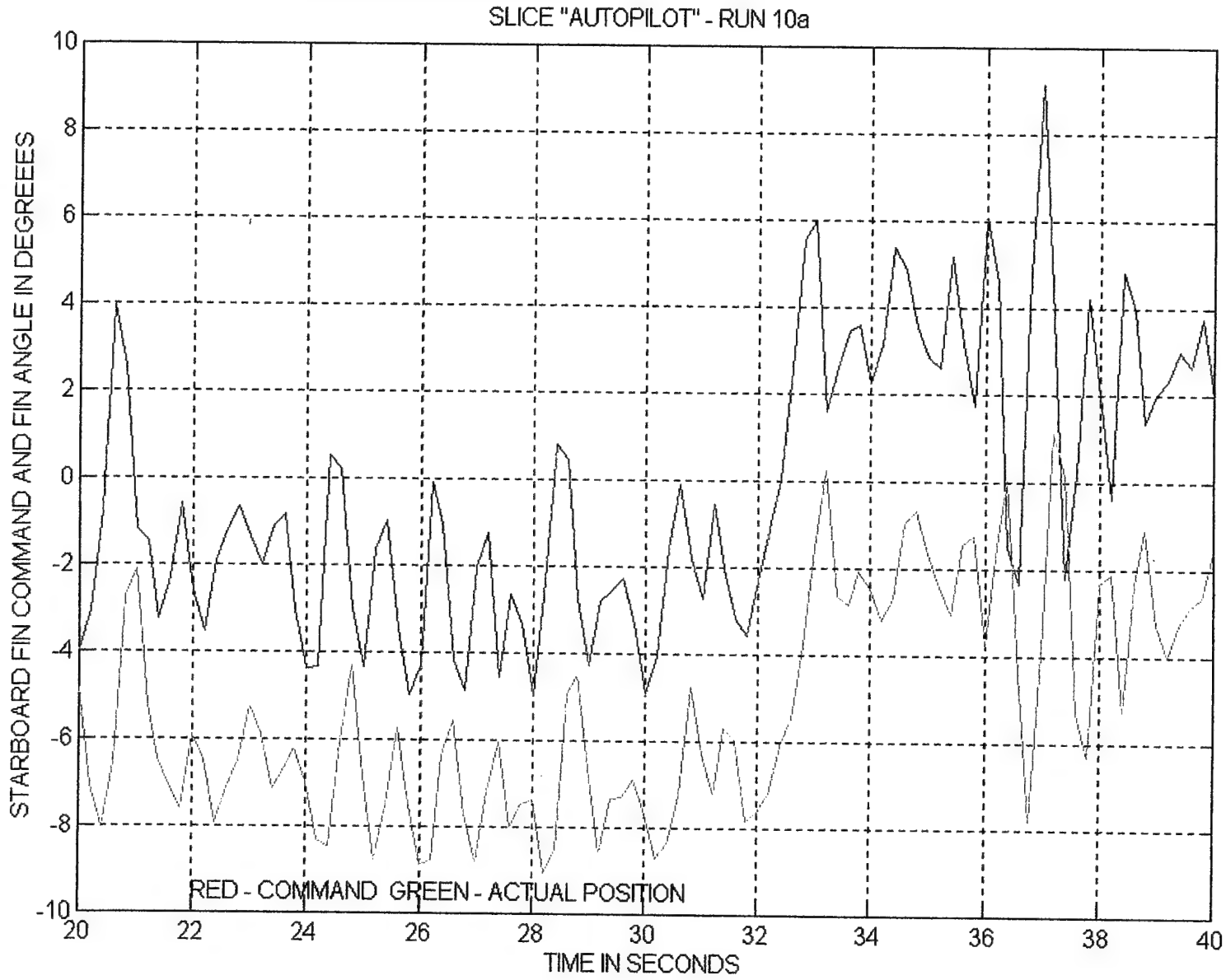

SLICE "AUTOPILOT" - RUN 10a
PITCH ANGLE IN DEGREEES
TIME IN SECONDS
2.5
2
1.5
1
0.5
0
-0.5
20
22
24
26
28
30
32
34
36
38
40

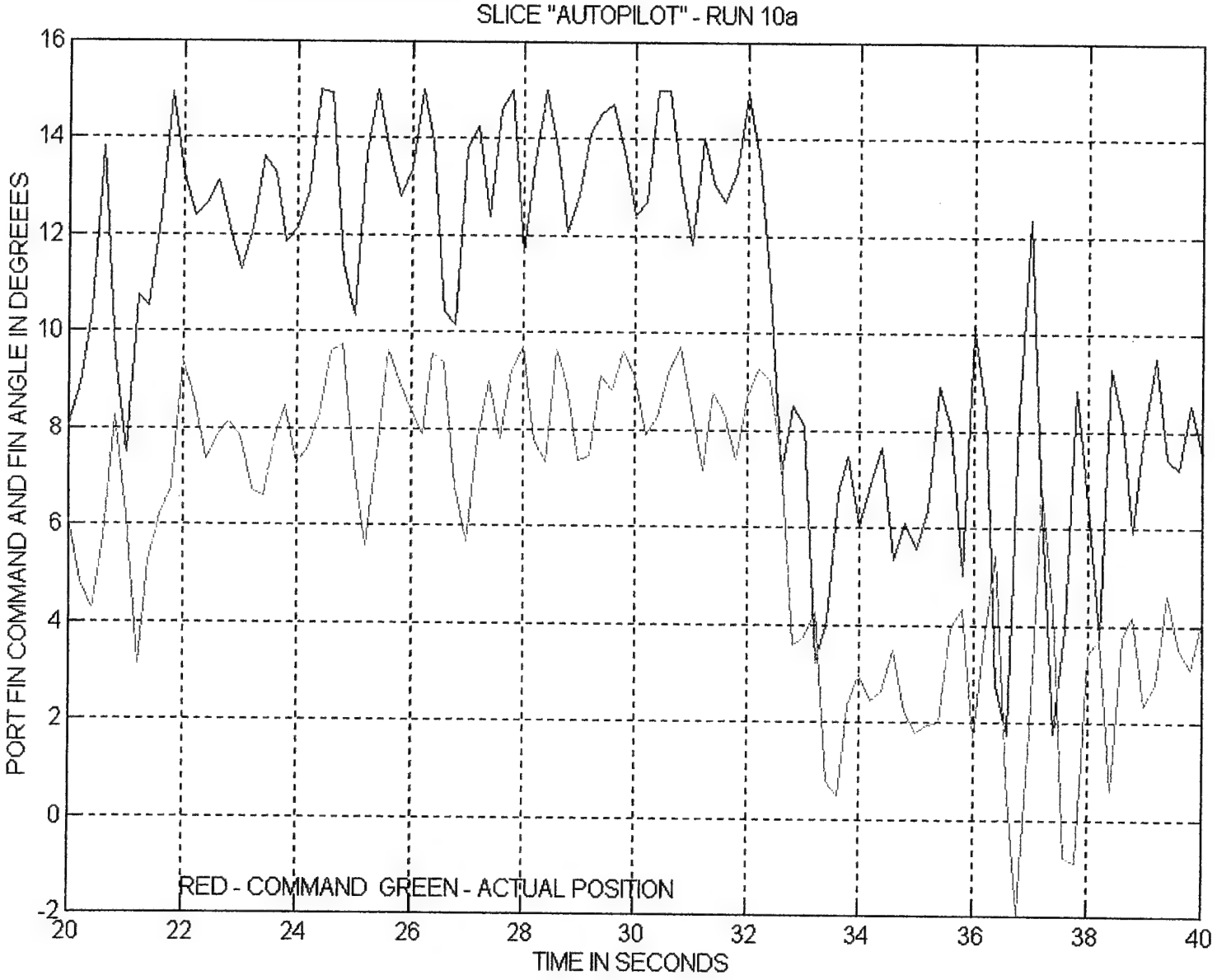

SLICE "AUTOPILOT" - RUN 10a
ROLL ANGLE IN DEGREEES
TIME IN SECONDS
1.5
1
0.5
0
-0.5
-1
-1.5
-2
20
22
24
26
28
30
32
34
36
38
40


SLICE "AUTOPILOT" - RUN 10a
YAW ANGLE IN DEGREEES
TIME IN SECONDS
93
92
91
90
89
88
87
86
85
84
83
20
22
24
26
28
30
32
34
36
38
40


SLICE "AUTOPILOT" - RUN 10a
PORT STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
-40
20
22
24
26
28
30
32
34
36
38
40
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE


SLICE "AUTOPILOT" - RUN 10a
PORT STABILIZER POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
-6
20
22
24
26
28
30
32
34
36
38
40


SLICE "AUTOPILOT" - RUN 10a
STARBOARD FIN COMMAND AND FIN ANGLE IN DEGREEES
10
8
6
4
2
0
-2
-4
-6
-8
-10
20
22
24
26
28
30
32
34
36
38
40
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION


SLICE "AUTOPILOT" - RUN 10a
PORT FIN COMMAND AND FIN ANGLE IN DEGREEES
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION
16
14
12
10
8
6
4
2
0
-2
20
22
24
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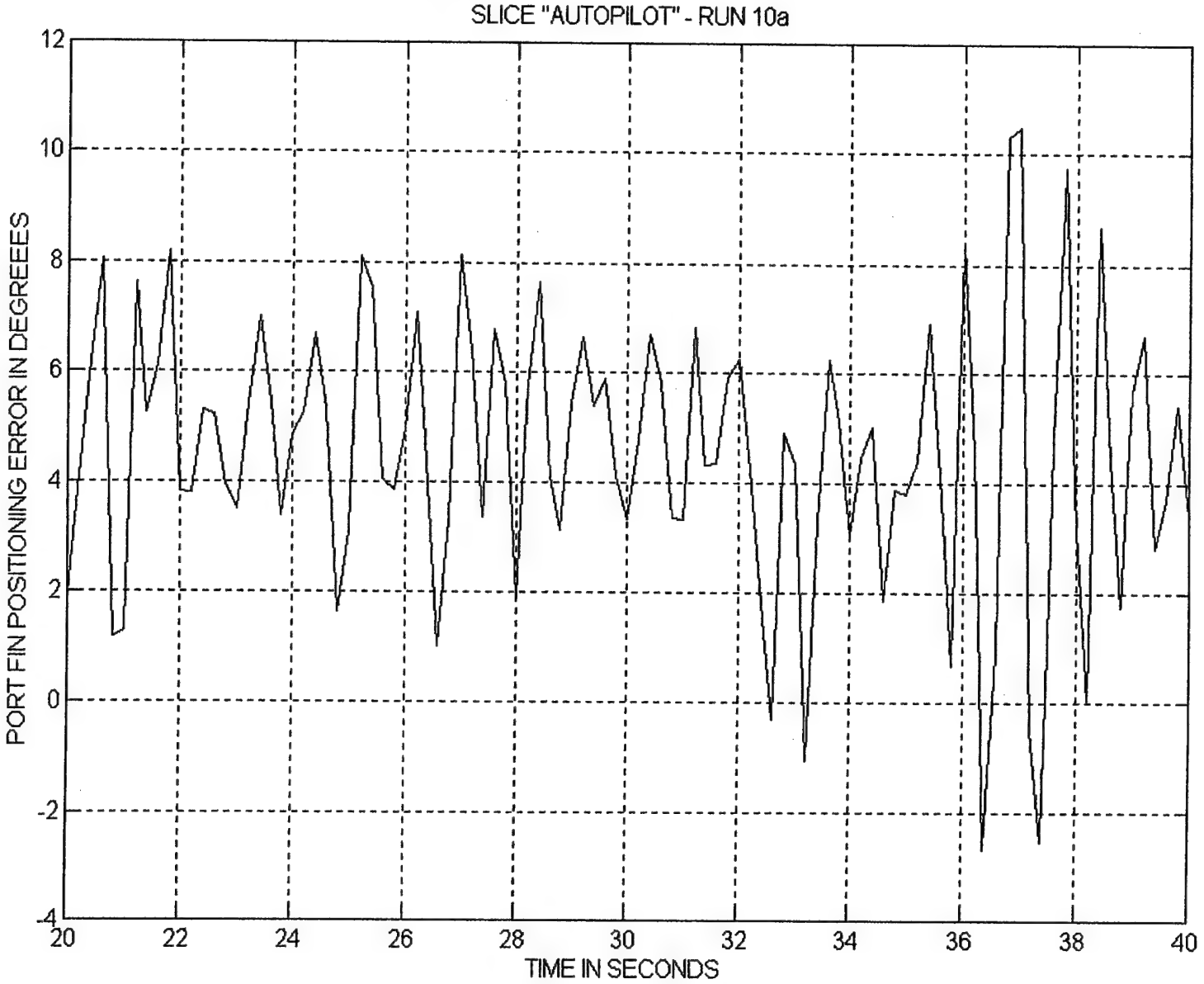
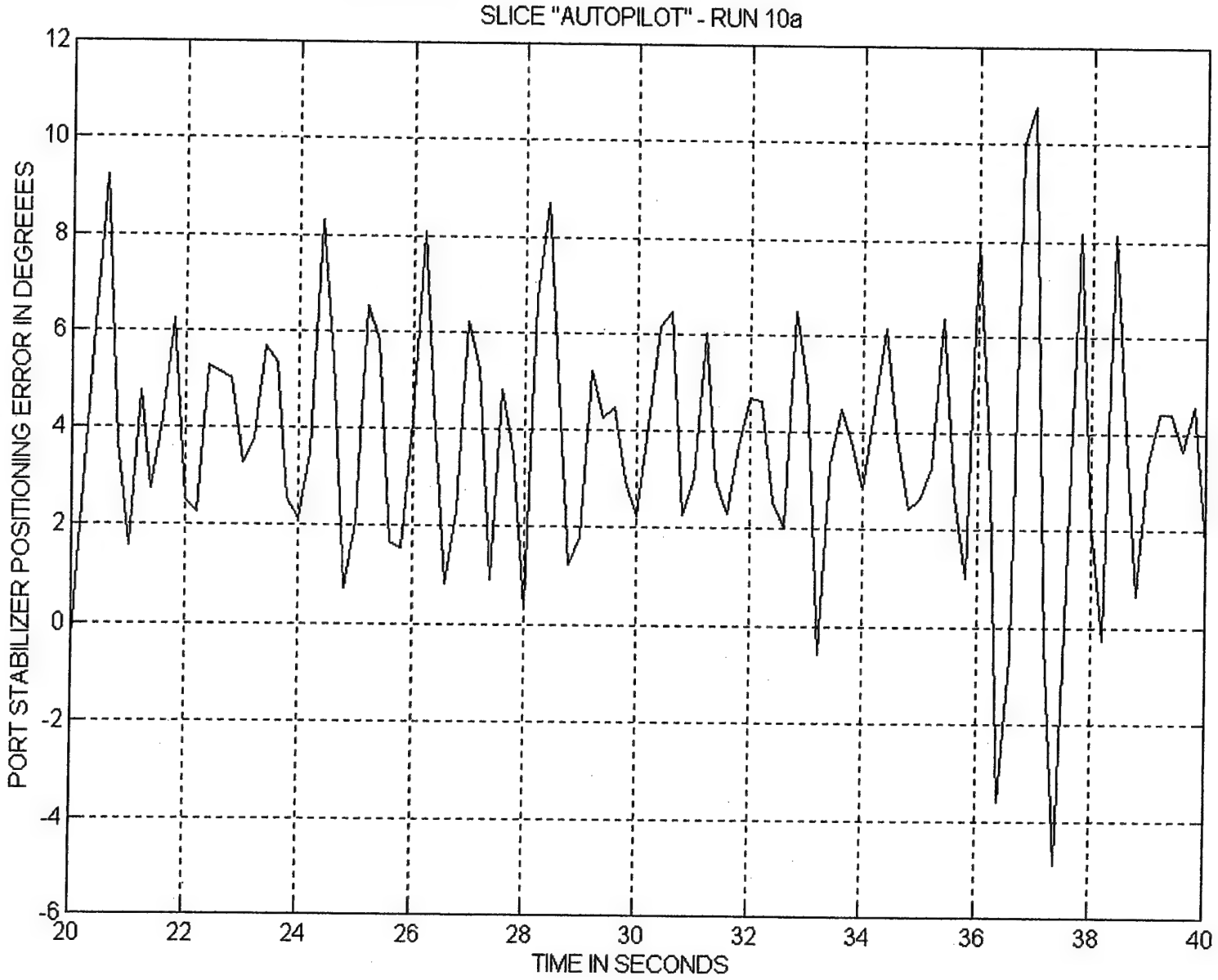
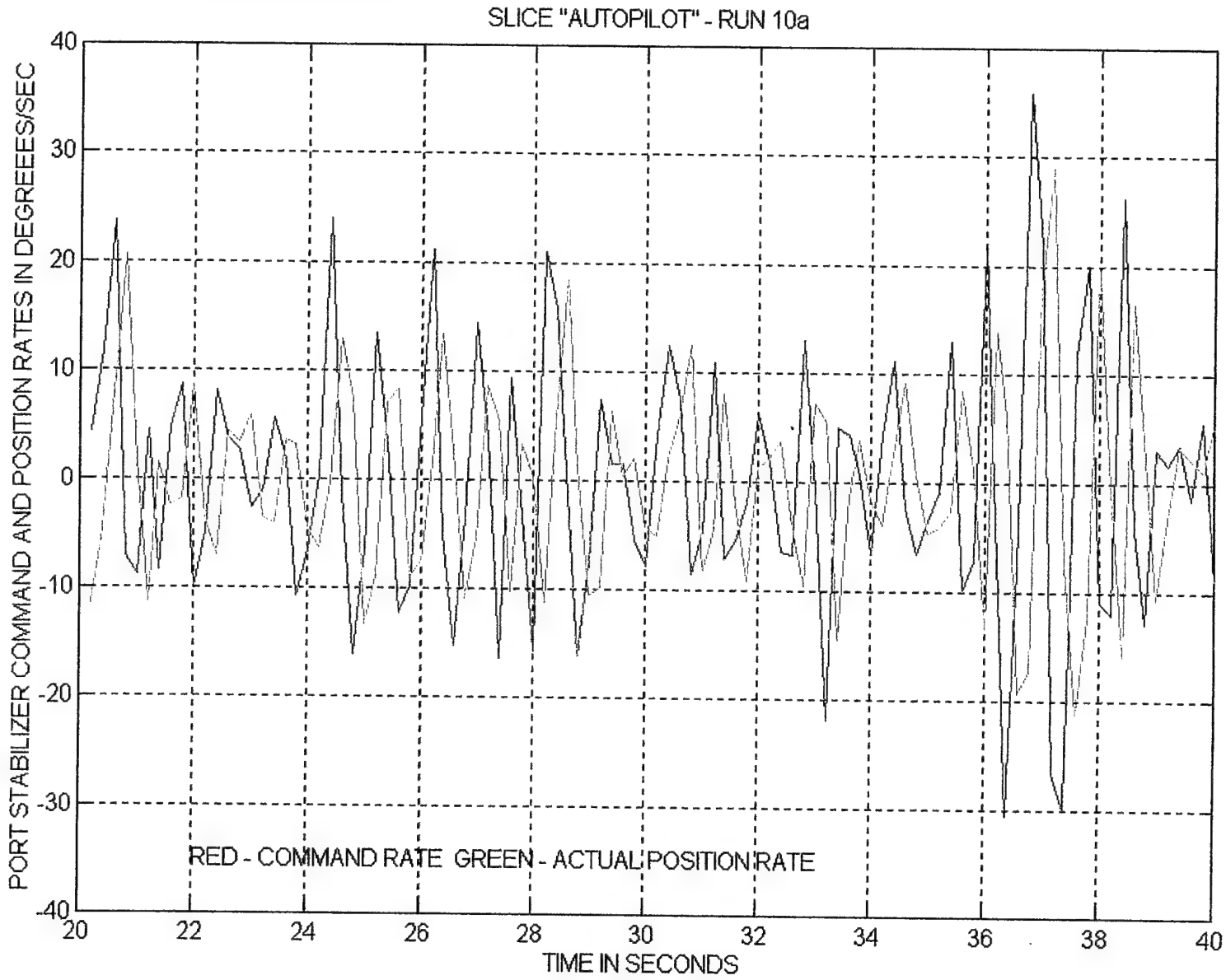
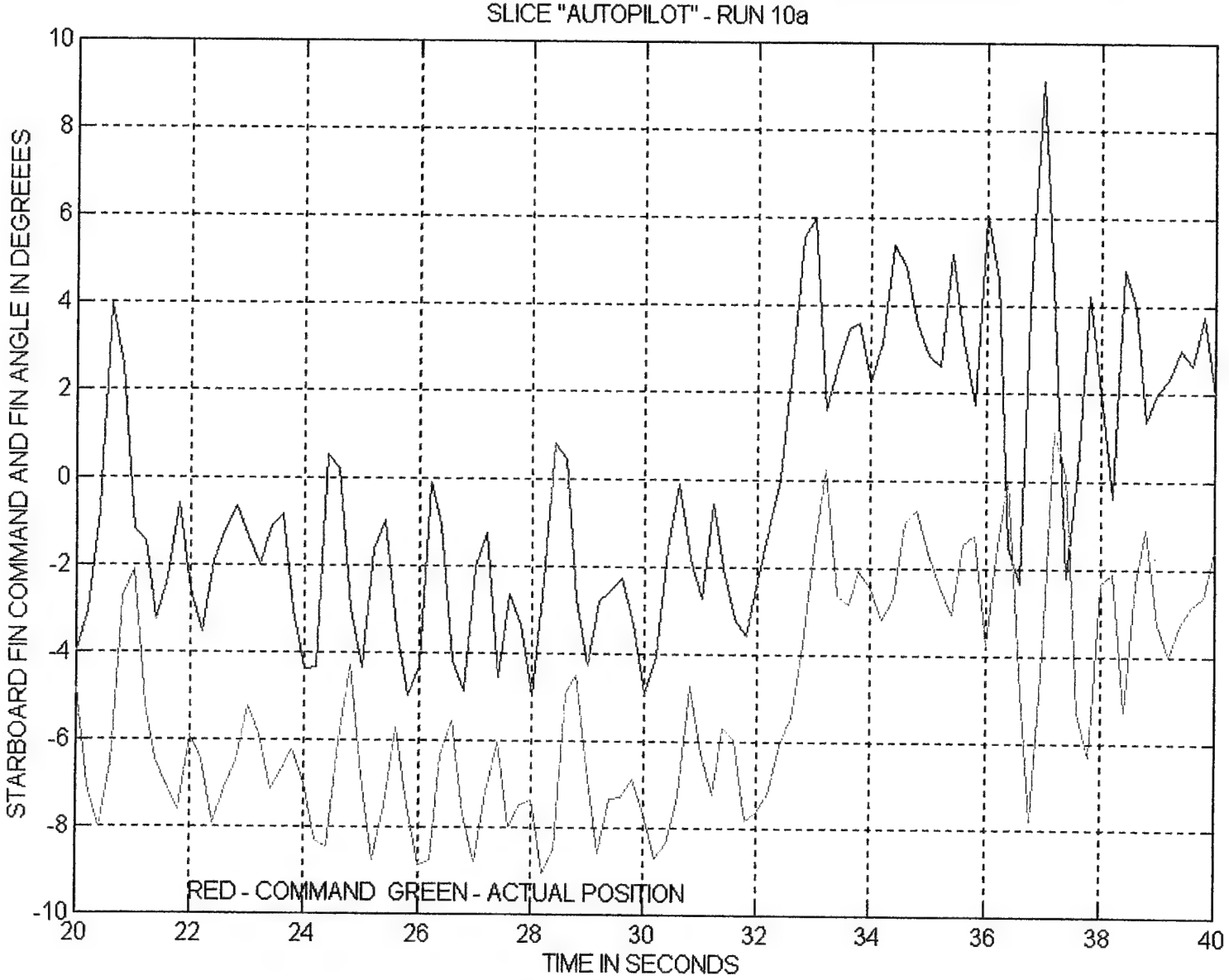
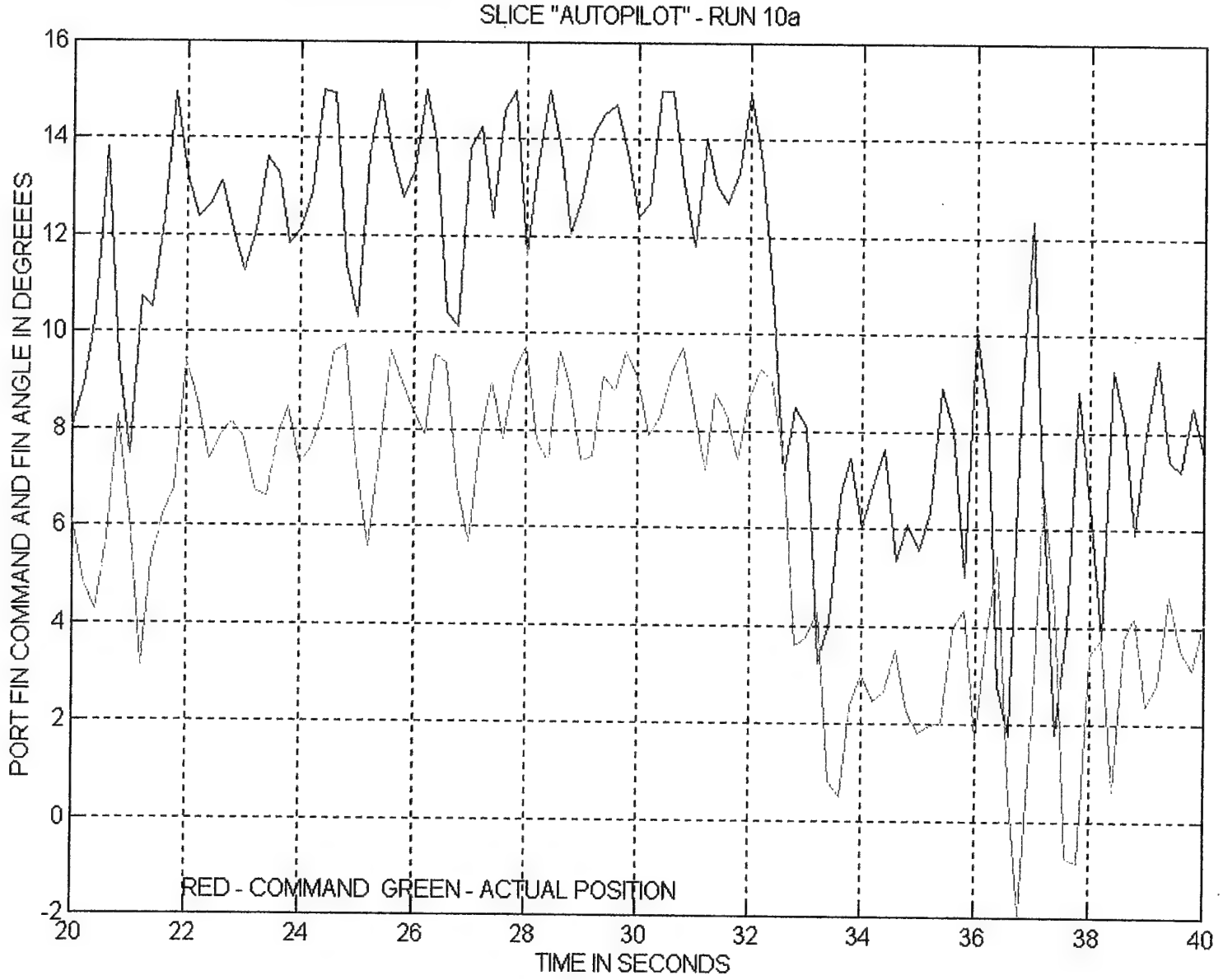
34
36
38
40

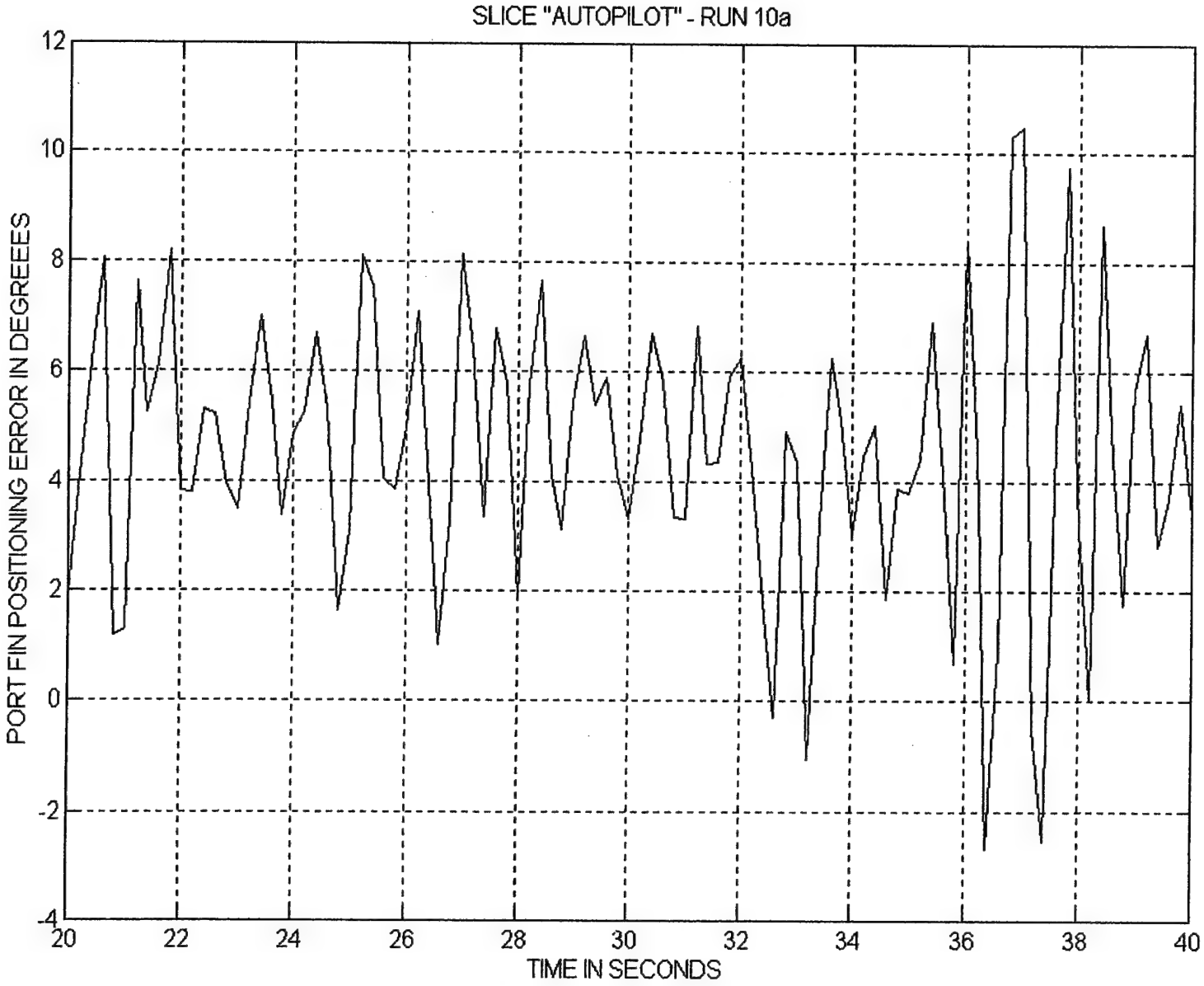

SLICE "AUTOPILOT" - RUN 10a
PORT FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
20
22
24
26
28
30
32
34
36
38
40

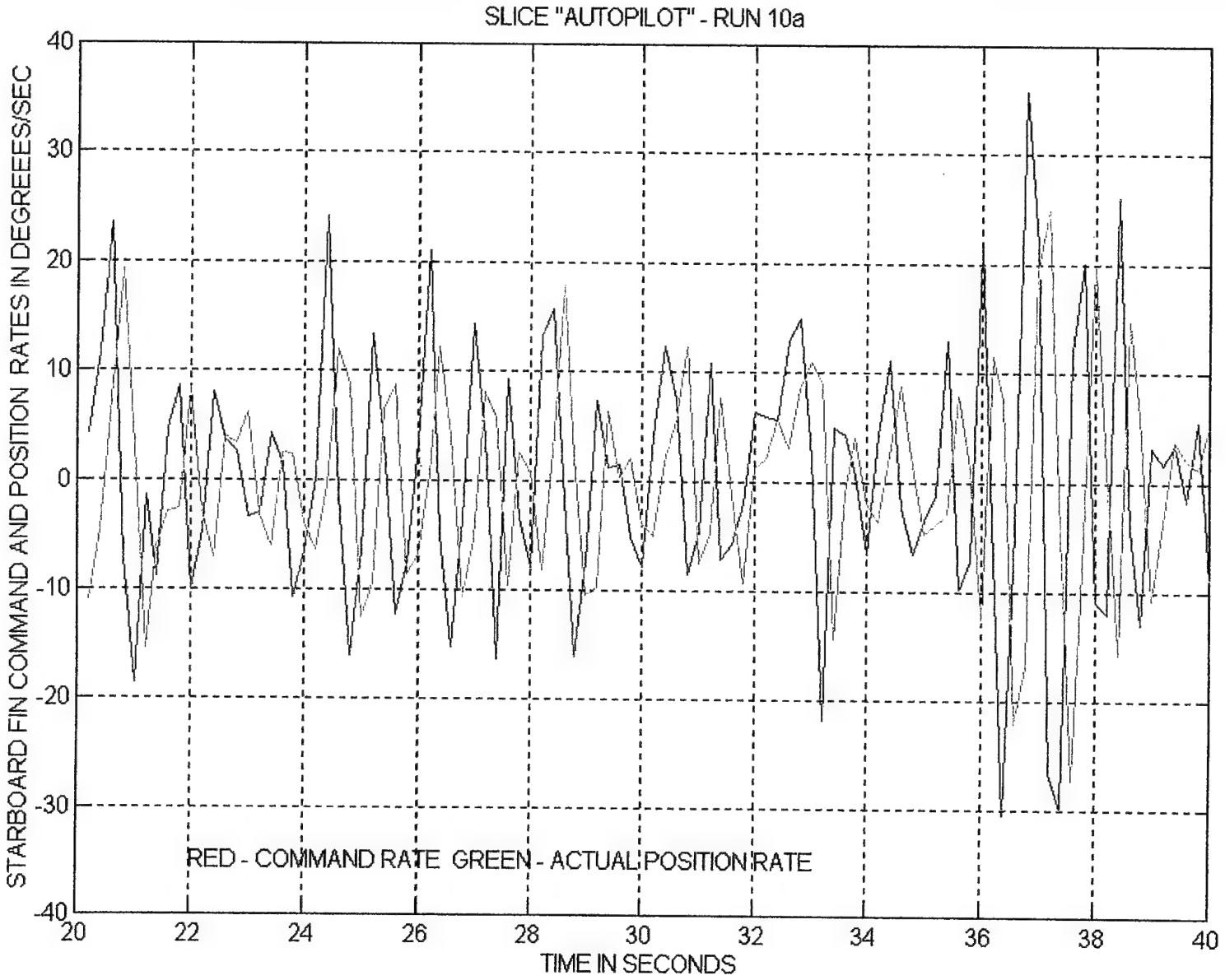

SLICE "AUTOPILOT" - RUN 10a
PORT STABILIZER POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
-6
20
22
24
26
28
30
32
34
36
38
40

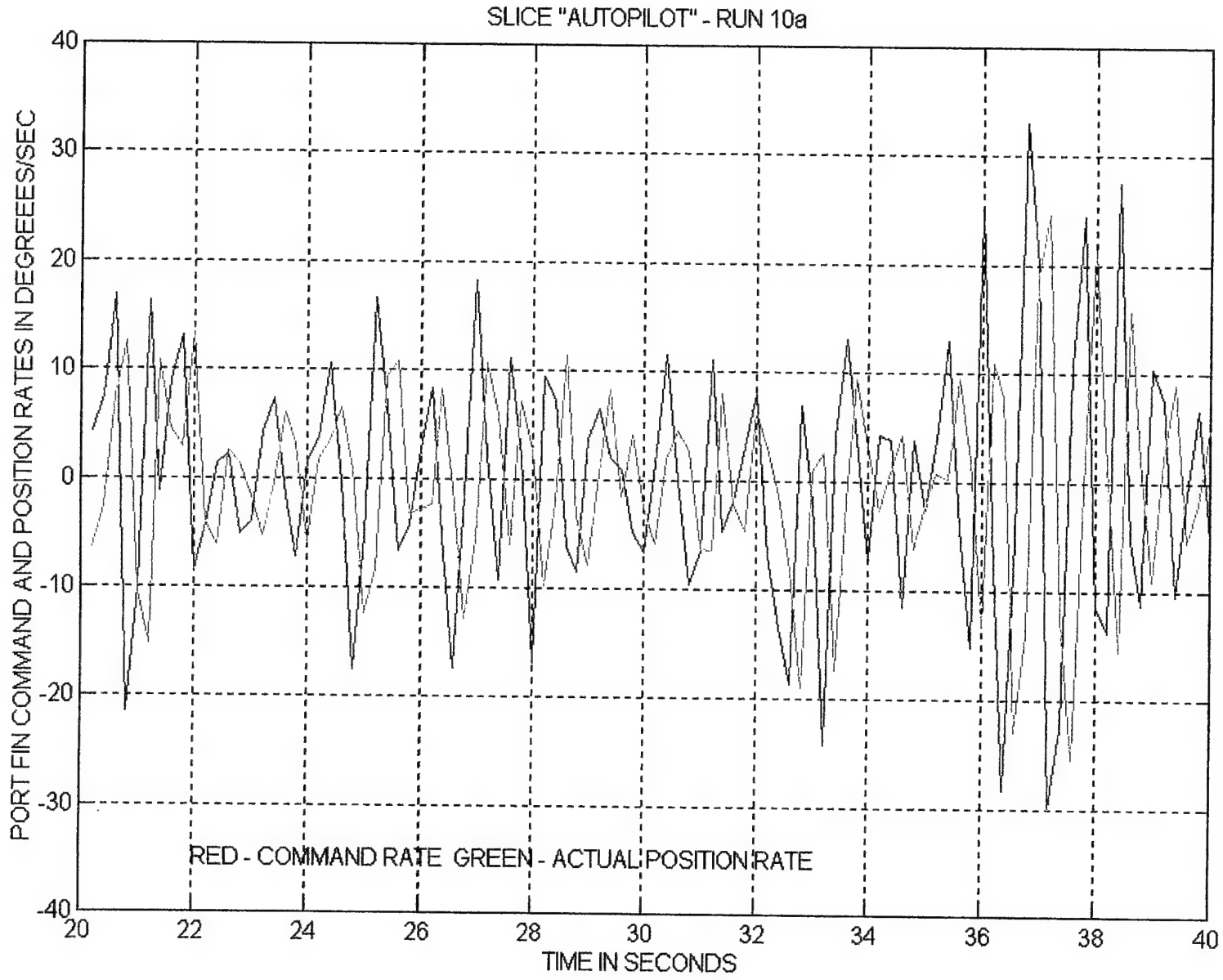

SLICE "AUTOPILOT" - RUN 10a
PORT STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
-40
20
22
24
26
28
30
32
34
36
38
40
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE


SLICE "AUTOPILOT" - RUN 10a
STARBOARD FIN COMMAND AND FIN ANGLE IN DEGREEES
10
8
6
4
2
0
-2
-4
-6
-8
-10
20
22
24
26
28
30
32
34
36
38
40
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION


SLICE "AUTOPILOT" - RUN 10a
PORT FIN COMMAND AND FIN ANGLE IN DEGREEES
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION
16
14
12
10
8
6
4
2
0
-2
20
22
24
26
28
30
32
34
36
38
40

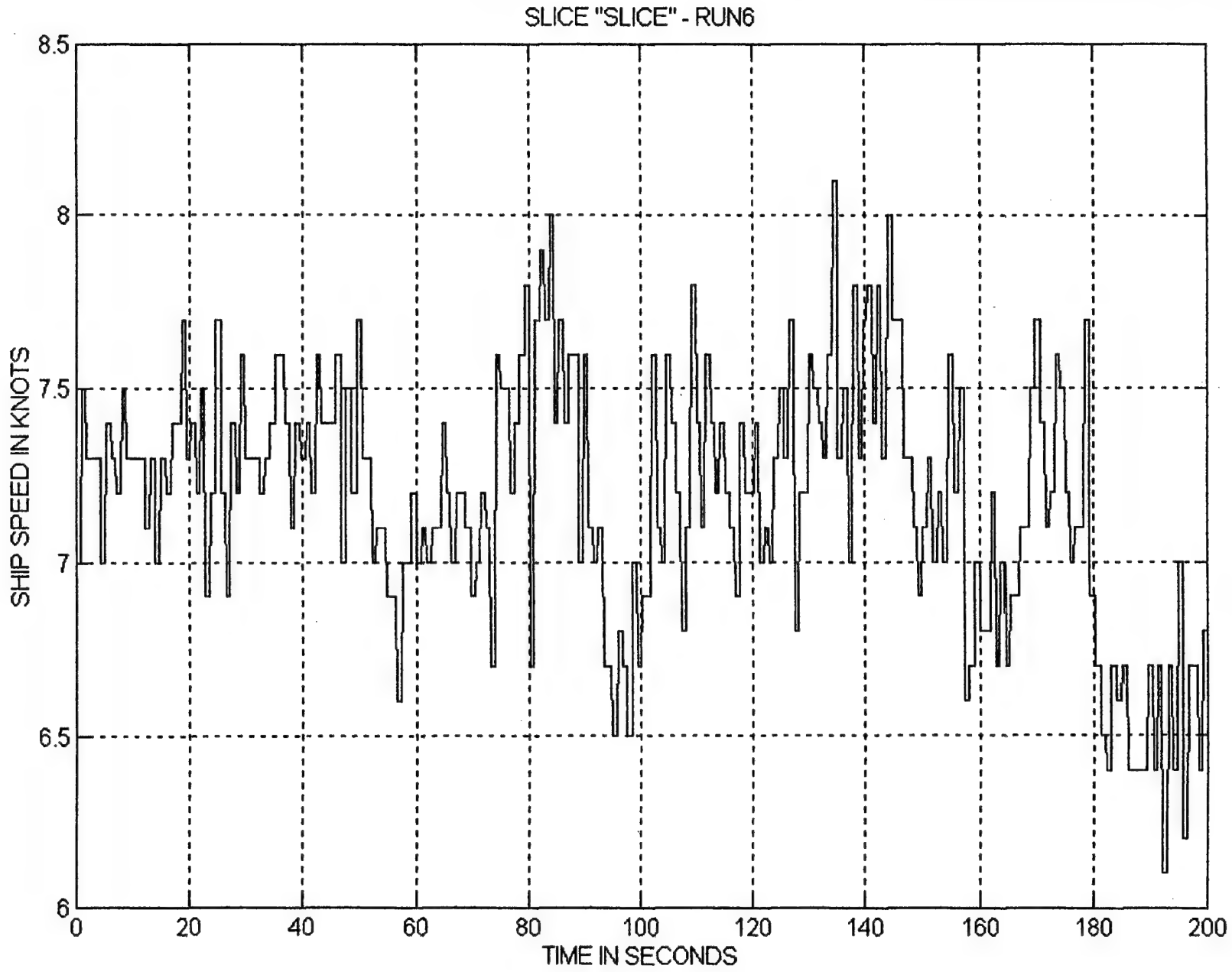

SLICE "AUTOPILOT" - RUN 10a
PORT FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
20
22
24
26
28
30
32
34
36
38
40

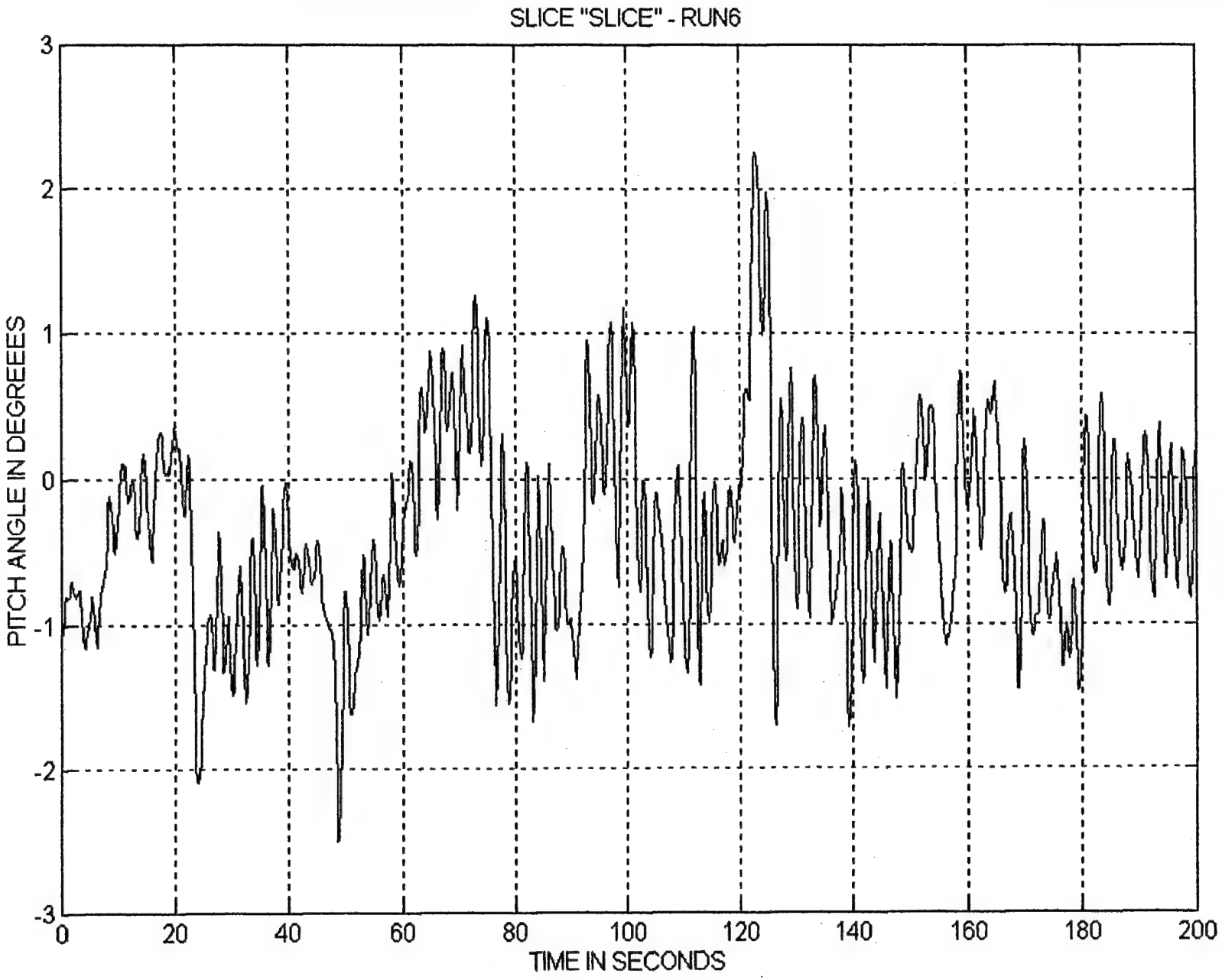

SLICE "AUTOPILOT" - RUN 10a
STARBOARD FIN COMMAND AND POSITION RATES IN DEGREEES/SEC
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE
40
30
20
10
0
-10
-20
-30
-40
20
22
24
26
28
30
32
34
36
38
40

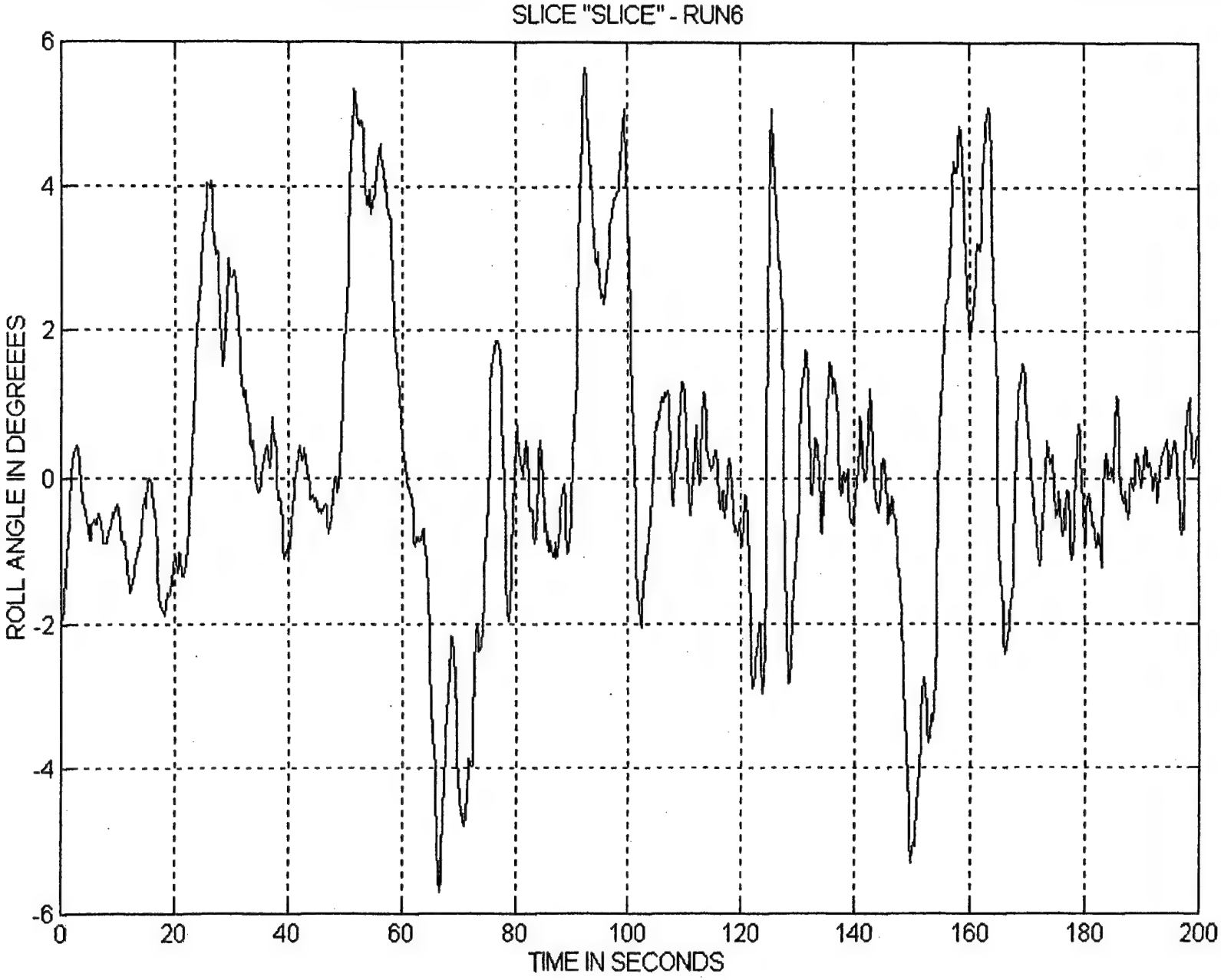

SLICE "AUTOPILOT" - RUN 10a
PORT FIN COMMAND AND POSITION RATES IN DEGREEES/SEC
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE
40
30
20
10
0
-10
-20
-30
-40
20
22
24
26
28
30
32
34
36
38
40

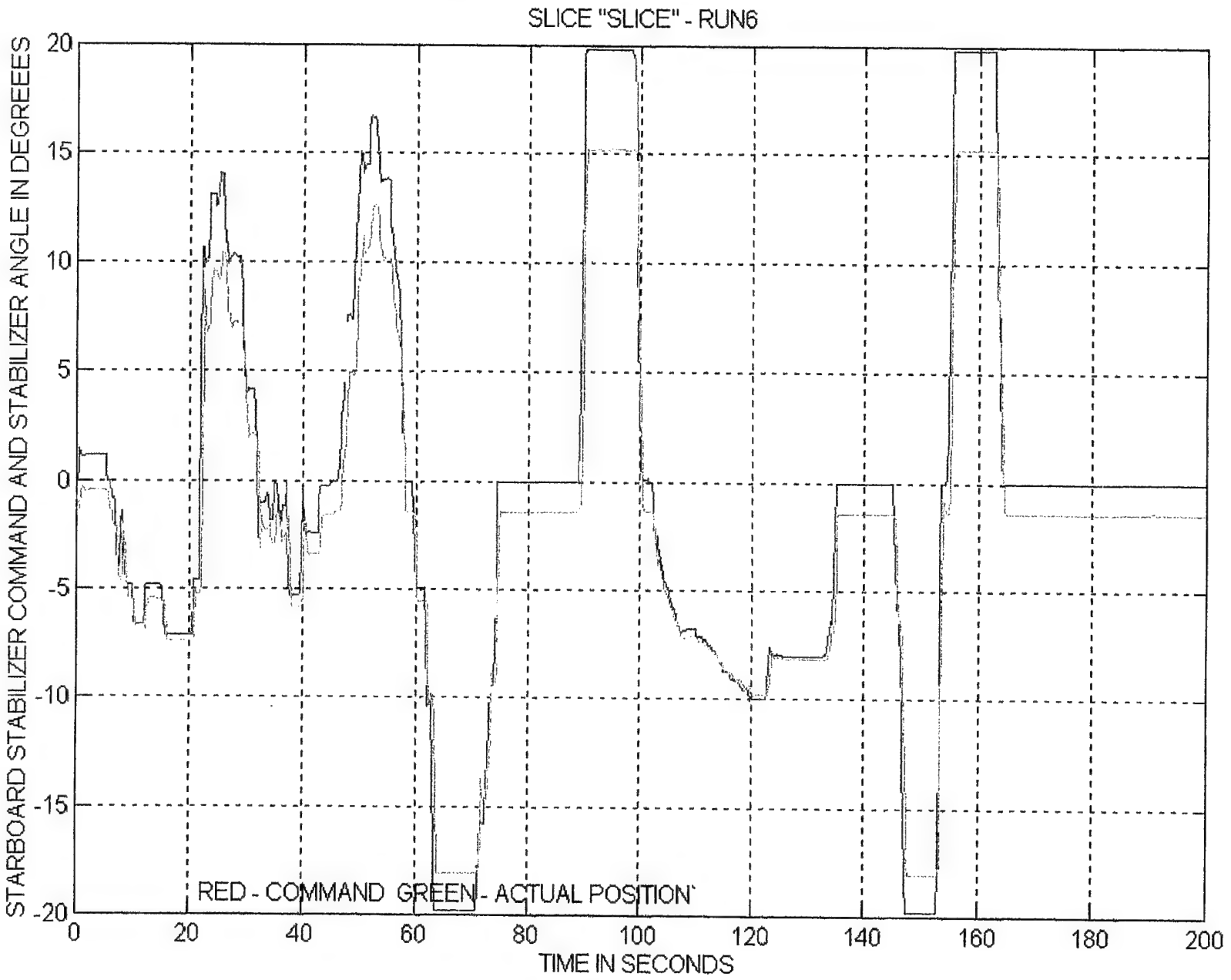
APPENDIX E

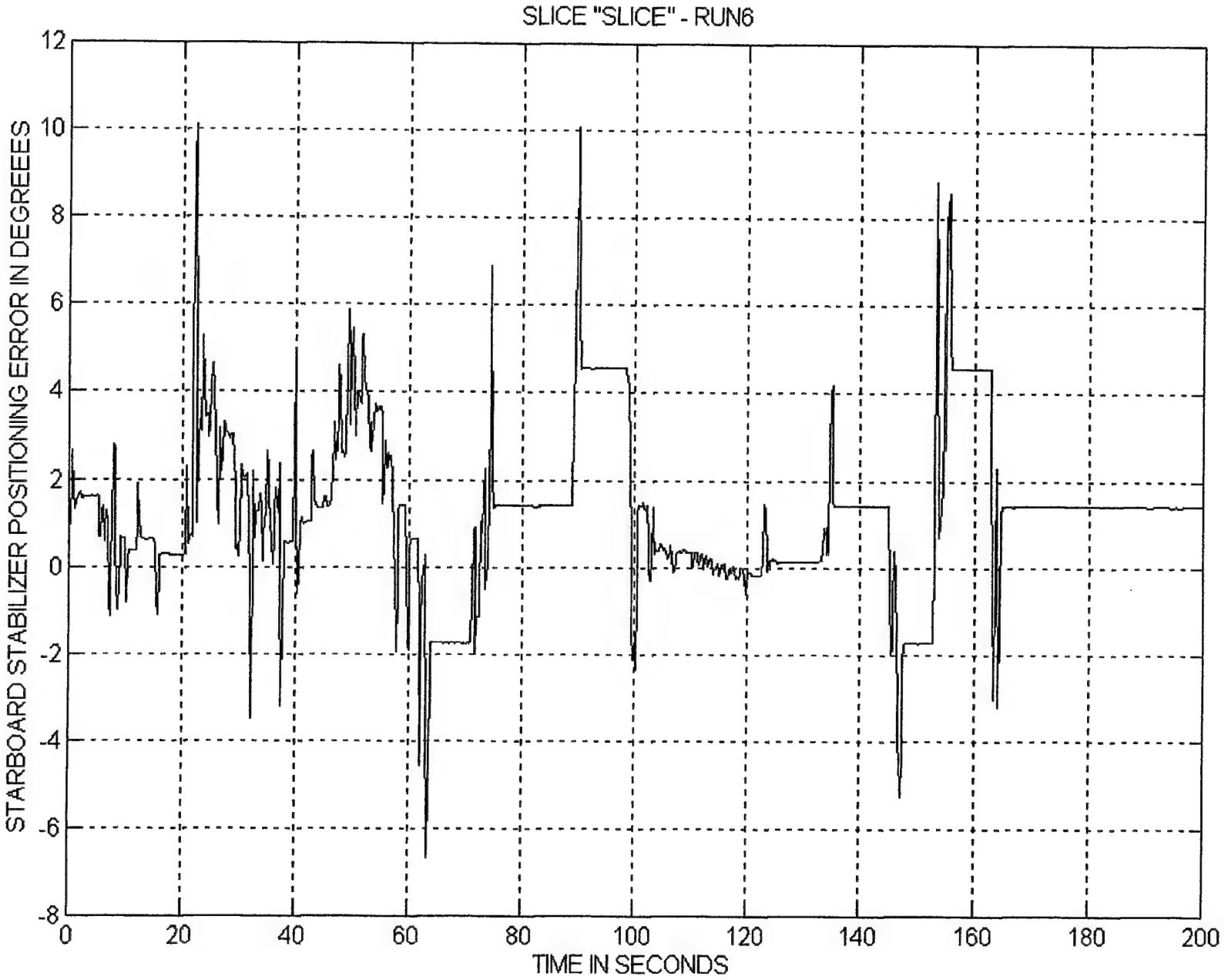
SLICE AUTOPILOT RUN ID Autoplilot_08_Nov00_09_57_41

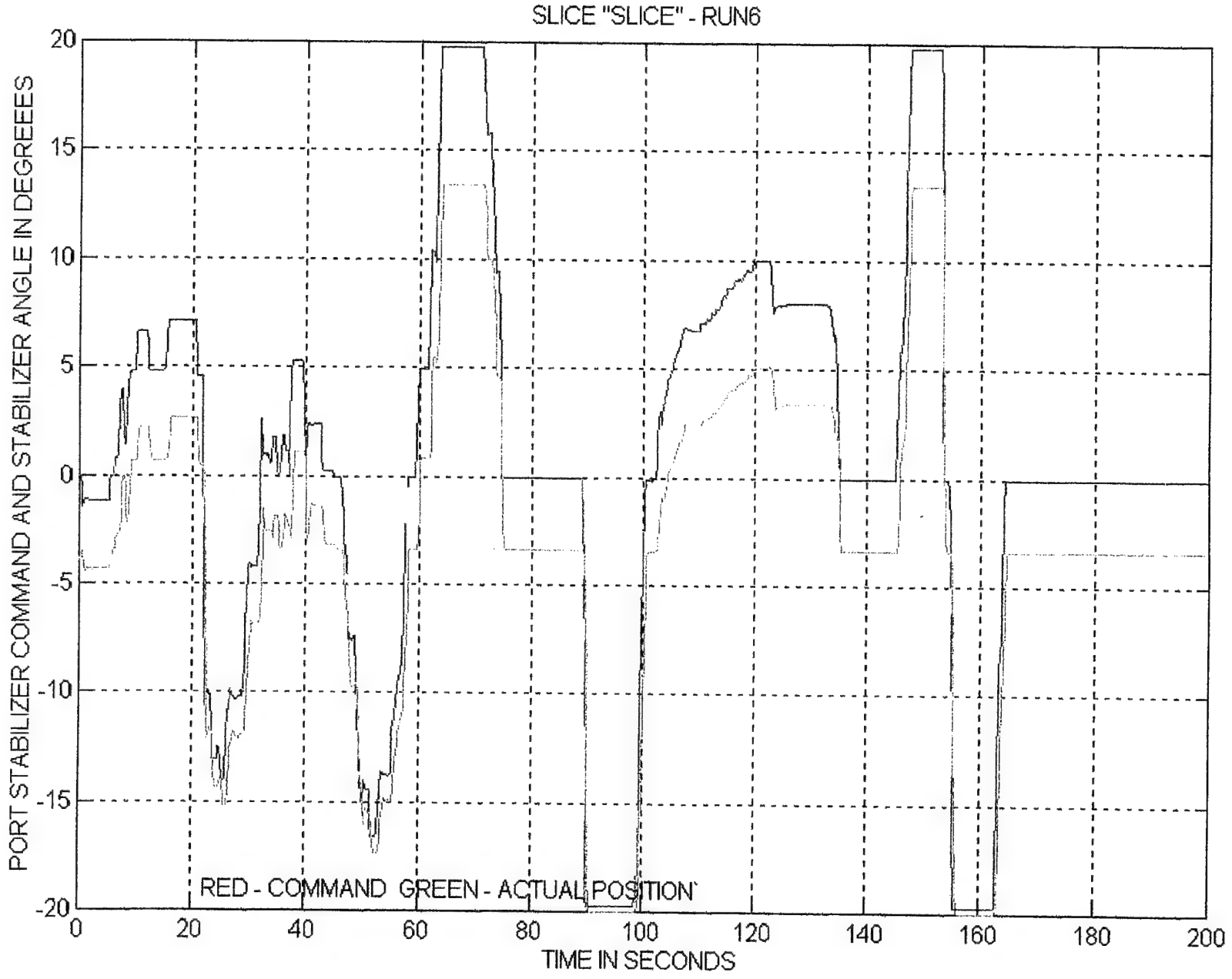

SLICE "SLICE" - RUN6
SHIP SPEED IN KNOTS
TIME IN SECONDS
8.5
8
7.5
7
6.5
6
0
20
40
60
80
100
120
140
160
180
200

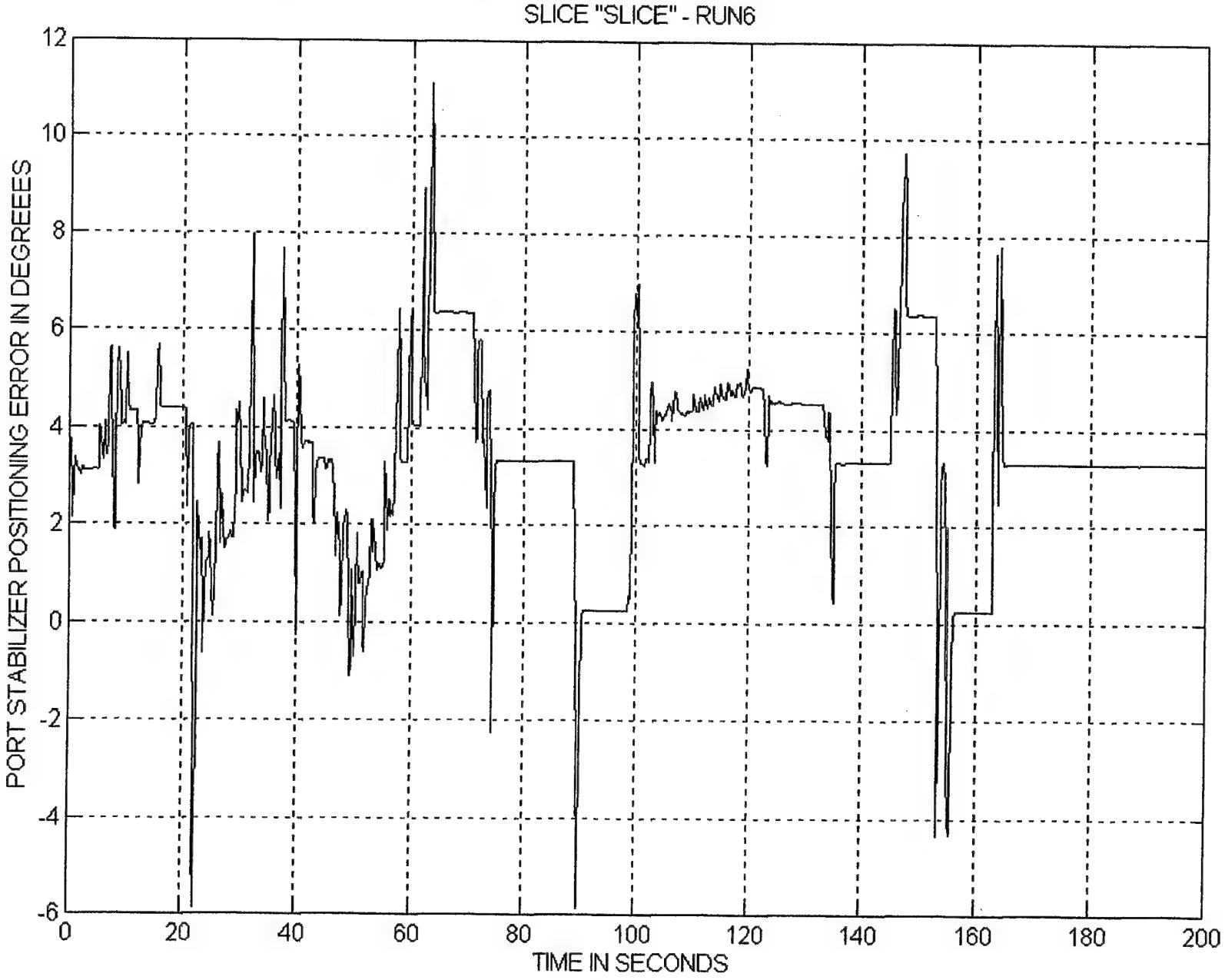

SLICE "SLICE" - RUN6
PITCH ANGLE IN DEGREEES
TIME IN SECONDS
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200

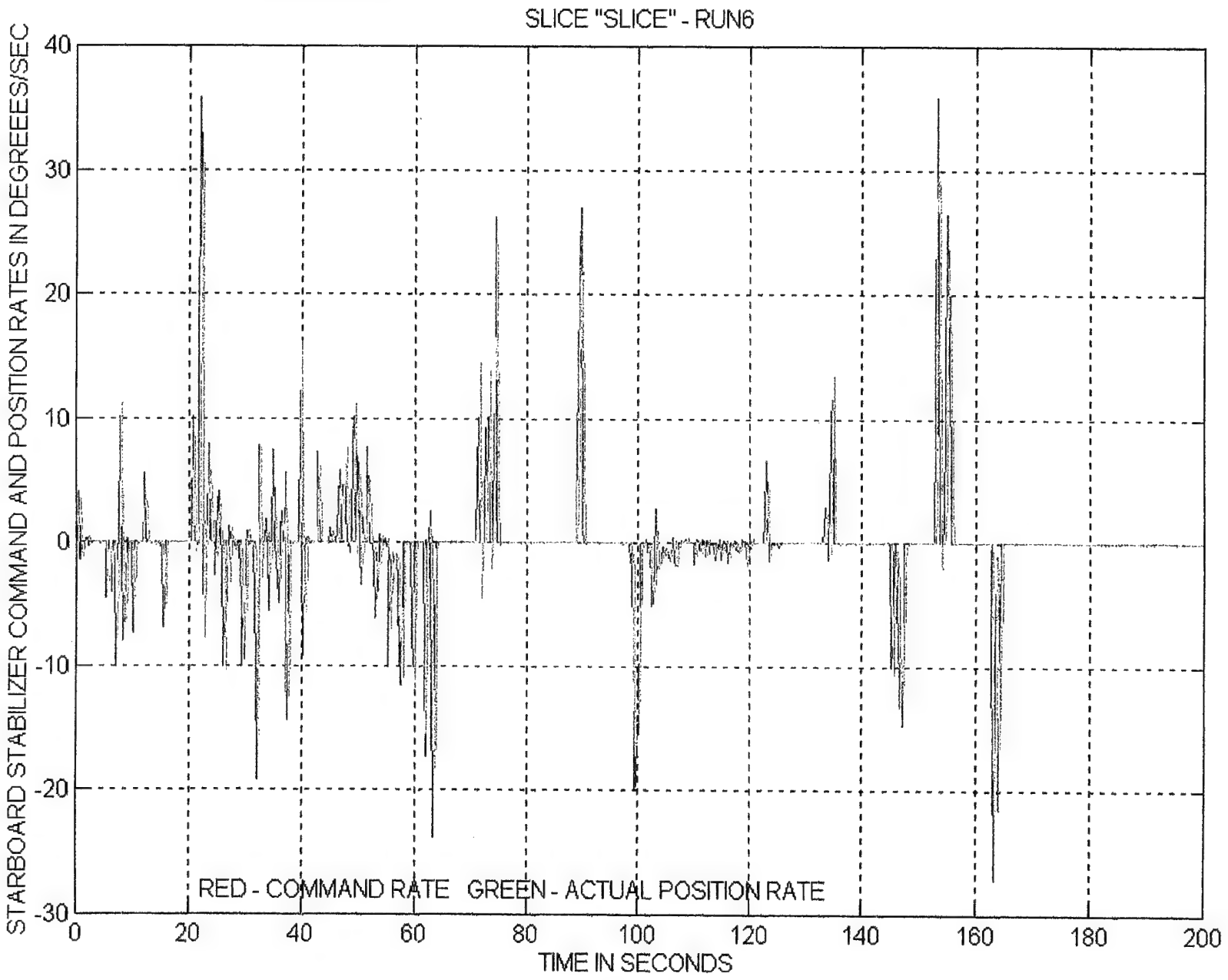

SLICE "SLICE" - RUN6
ROLL ANGLE IN DEGREEES
TIME IN SECONDS
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
180
200

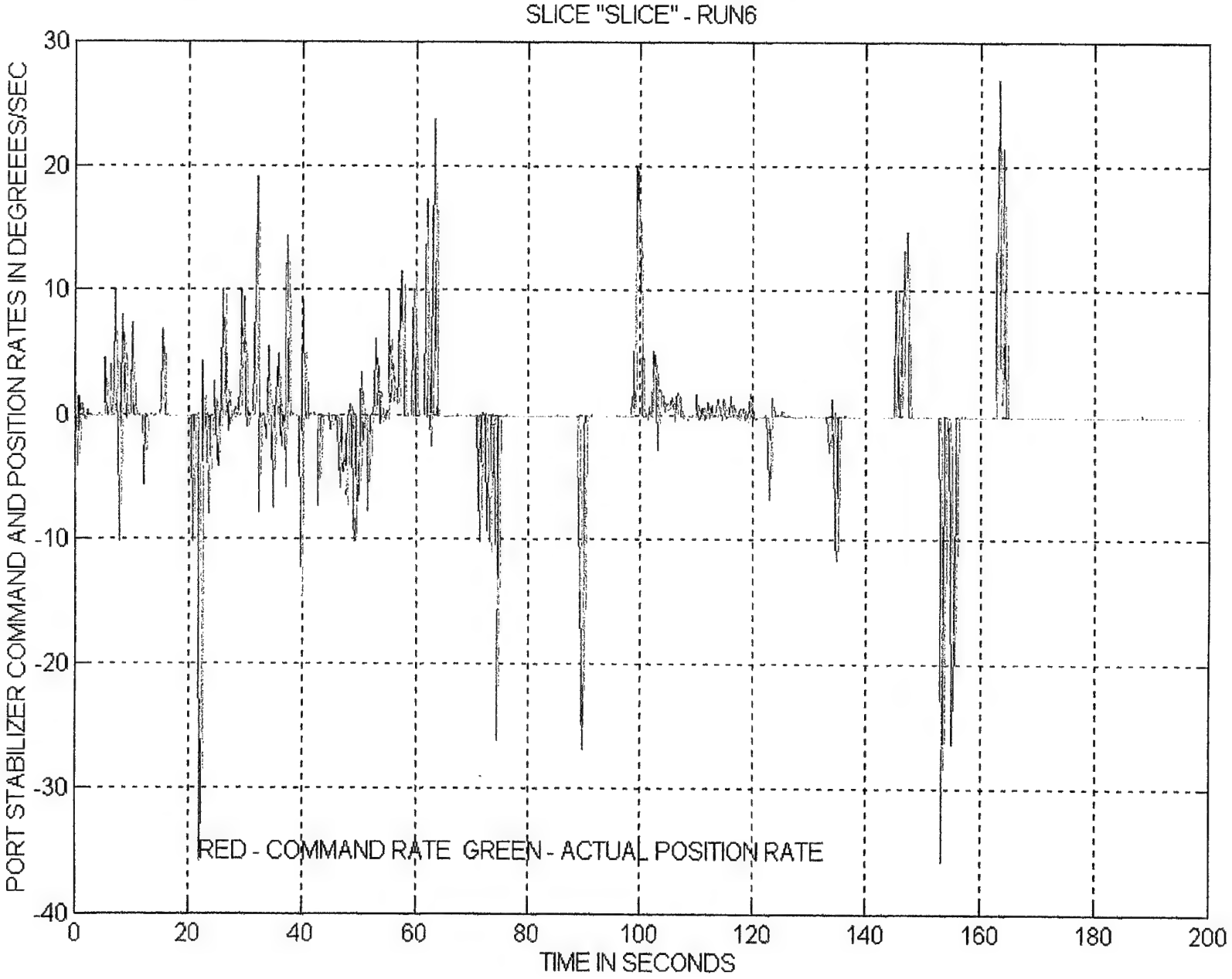

SLICE "SLICE" - RUN6
STARBOARD STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION

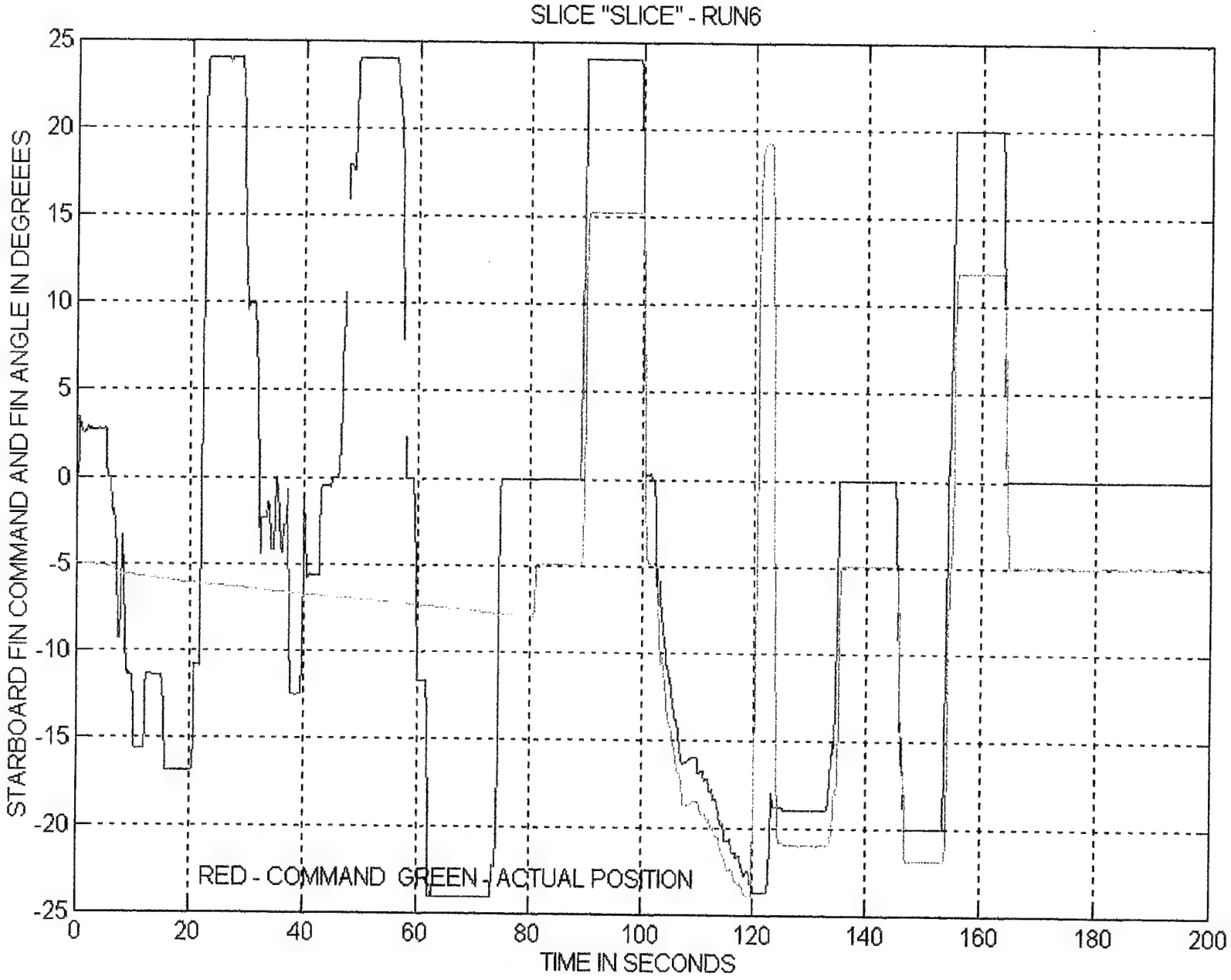

SLICE "SLICE" - RUN6
STARBOARD STABILIZER POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
-6
-8
0
20
40
60
80
100
120
140
160
180
200

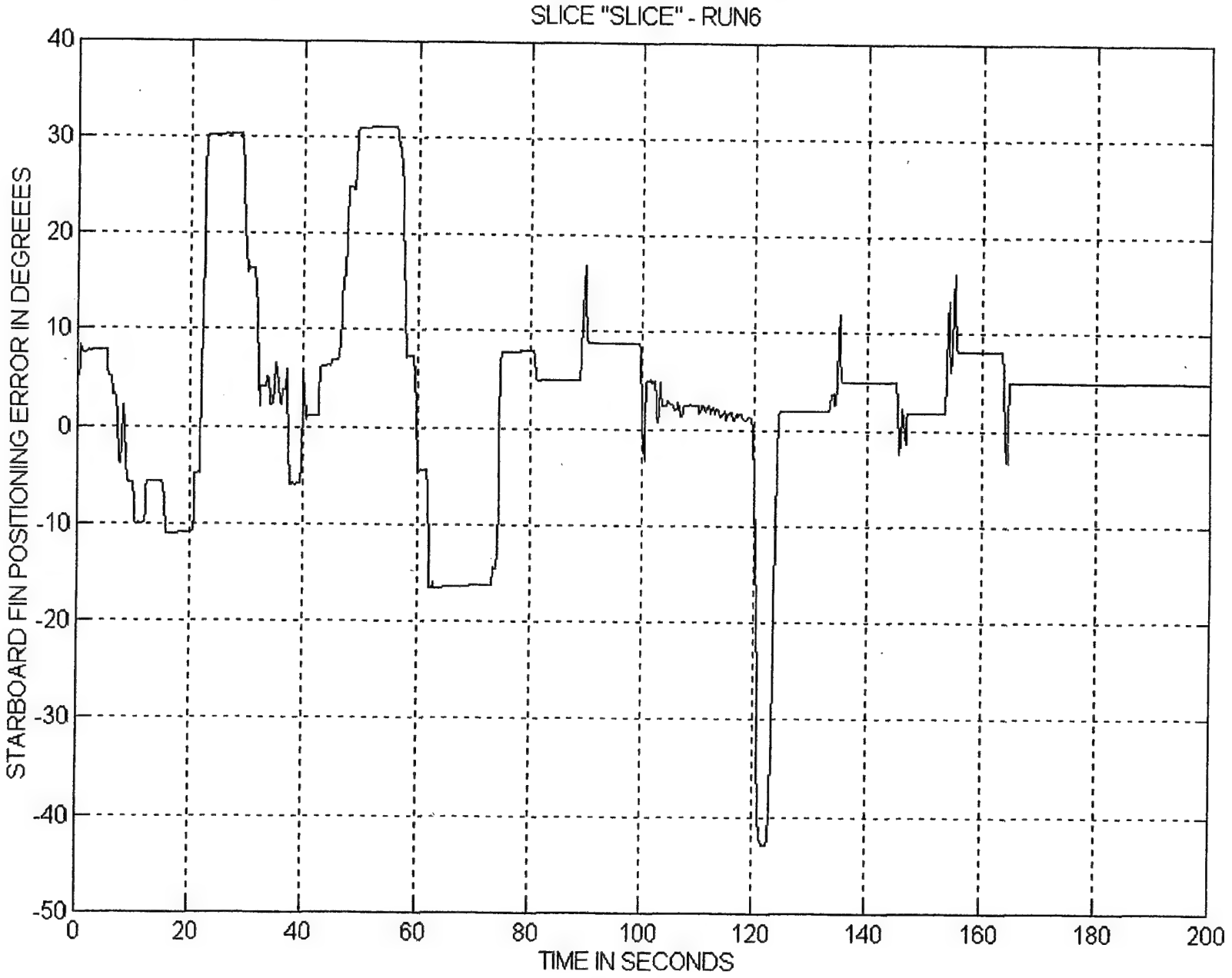

SLICE "SLICE" - RUN6
PORT STABILIZER COMMAND AND STABILIZER ANGLE IN DEGREEES
20
15
10
5
0
-5
-10
-15
-20
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION


SLICE "SLICE" - RUN6
PORT STABILIZER POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
12
10
8
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
180
200


SLICE "SLICE" - RUN6
STARBOARD STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
40
30
20
10
0
-10
-20
-30
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE


SLICE "SLICE" - RUN6
PORT STABILIZER COMMAND AND POSITION RATES IN DEGREEES/SEC
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE


SLICE "SLICE" - RUN6
STARBOARD FIN COMMAND AND FIN ANGLE IN DEGREEES
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
20
40
60
80
100
120
140
160
180
200
TIME IN SECONDS
RED - COMMAND GREEN - ACTUAL POSITION


SLICE "SLICE" - RUN6
STARBOARD FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
40
30
20
10
0
-10
-20
-30
-40
-50
0
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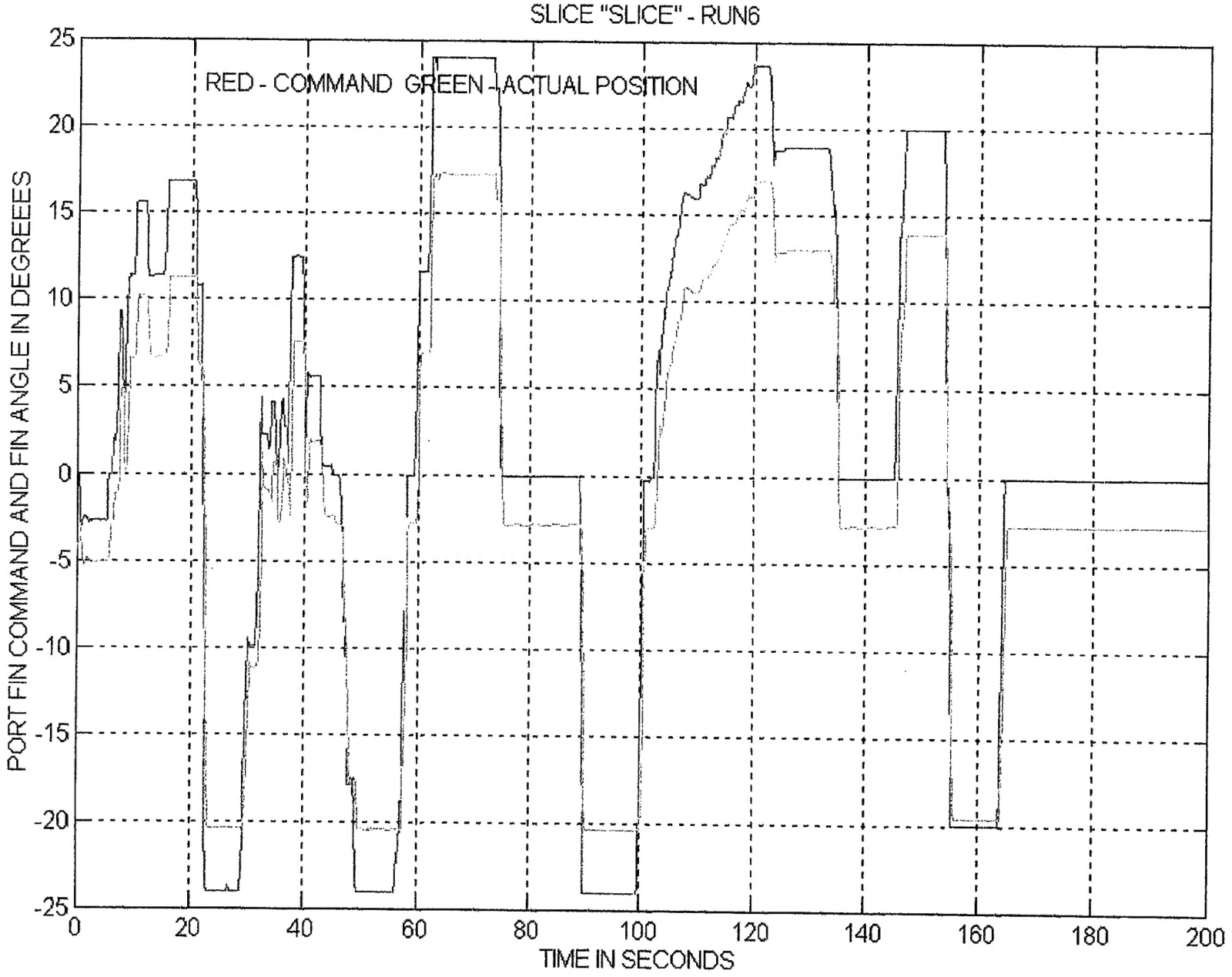
40
60
80
100
120
140
160
180
200


SLICE "SLICE" - RUN6
RED - COMMAND GREEN - ACTUAL POSITION
PORT FIN COMMAND AND FIN ANGLE IN DEGREEES
TIME IN SECONDS
25
20
15
10
5
0
-5
-10
-15
-20
-25
0
20
40
60
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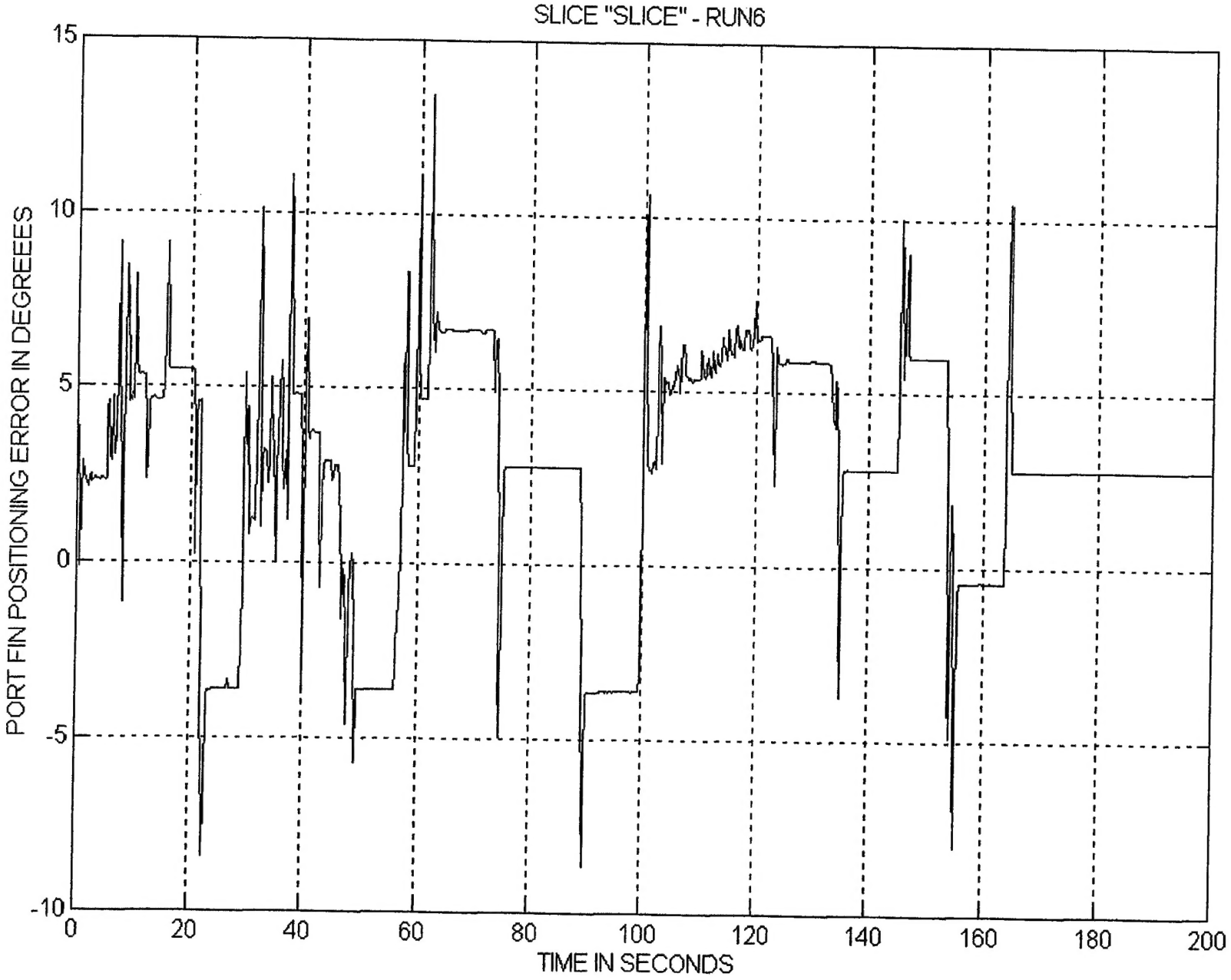
140
160
180
200


SLICE "SLICE" - RUN6
PORT FIN POSITIONING ERROR IN DEGREEES
TIME IN SECONDS
15
10
5
0
-5
-10
0
20
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60
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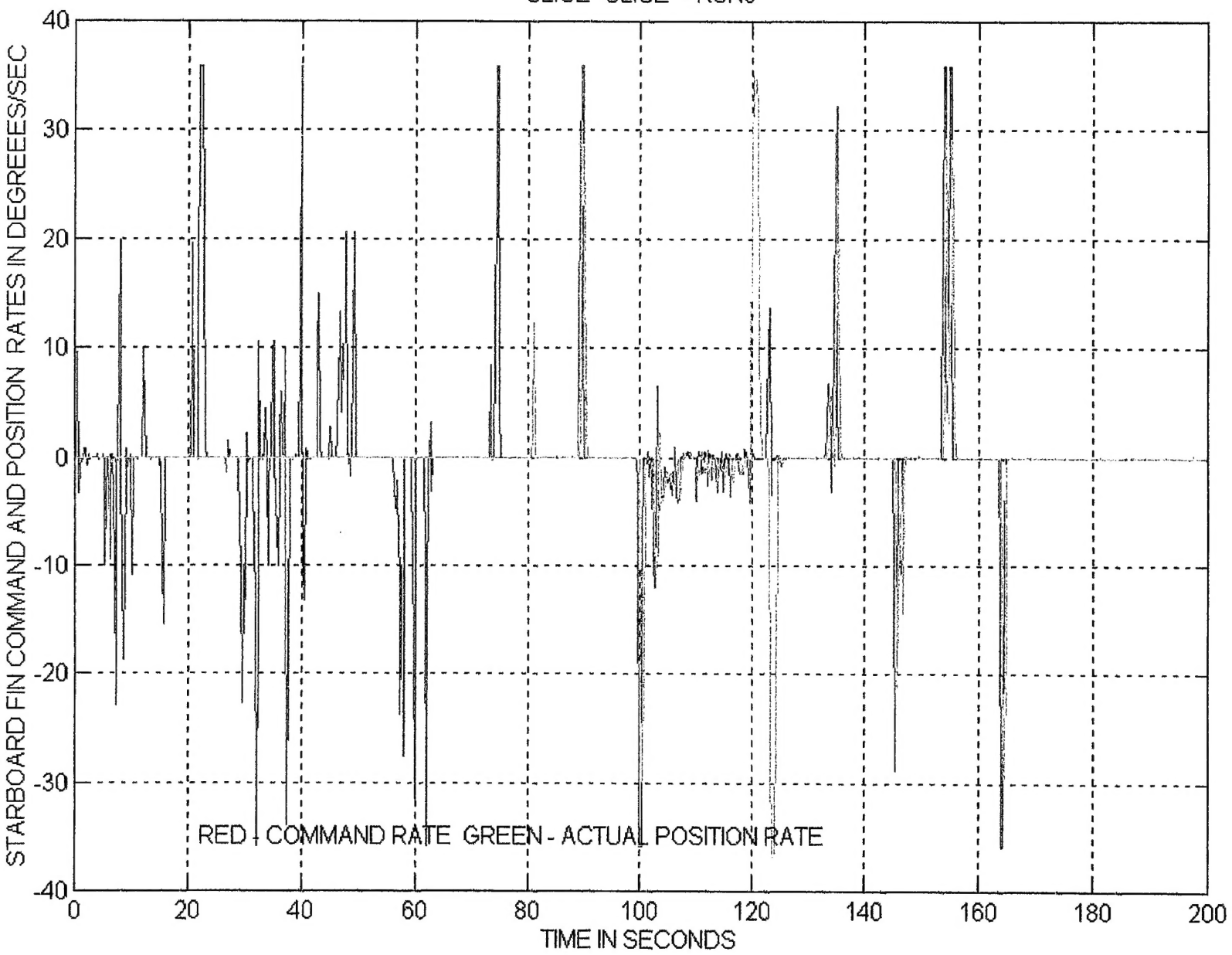
140
160
180
200


SLICE "SLICE" - RUN6
STARBOARD FIN COMMAND AND POSITION RATES IN DEGREEES/SEC
TIME IN SECONDS
RED - COMMAND RATE GREEN - ACTUAL POSITION RATE
40
30
20
10
0
-10
-20
-30
-40
0
20
40
60
80
100
120
140
160
180
200

REPORT DOCUMENTATION PAGE

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OMB No. 0704-0188

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14. ABSTRACT

This report summarizes the effort to review existing documentation and at-sea test results and assess performance of the SLICE ship control system. At-sea data taken by NSWC-Carderock, Lockheed Martin and documentation provided by Lockheed Martin provided the baseline information to conduct the assessment. The assessment focused on the SLICE ship control hardware and software including: the control surfaces; actuation system; motion sensors; control computer and control algorithms. Seakeeping performance improvement with ride control was not demonstrated during NSWC at-sea testing. Lack of recording of the position command signals to the control surfaces prevented a detailed analysis control surface actuator performance. Analysis of selected test runs from the Lockheed -Martin at-sea testing effort identified some problem areas as detailed in this report.

15. SUBJECT TERMS

SLICE/trailer; Control sytems; High speed hull forms; Control dynamics; At sea testing

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